EMOTION AND MOTION: AGE-RELATED DIFFERENCES IN RECOGNIZING VIRTUAL AGENT FACIAL EXPRESSIONS

A Thesis
Presented to
The Academic Faculty

by

Cory-Ann Smarr

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in the
School of Psychology

Georgia Institute of Technology
December 2011

EMOTION AND MOTION: AGE-RELATED DIFFERENCES IN RECOGNIZING VIRTUAL AGENT FACIAL EXPRESSIONS

Approved by:

Dr. Arthur D. Fisk, Advisor
School of Psychology
Georgia Institute of Technology

Dr. Gregory M. Corso
School of Psychology
Georgia Institute of Technology

Dr. Wendy A. Rogers
School of Psychology
Georgia Institute of Technology

Date Approved: April 18, 2011

ACKNOWLEDGEMENTS

This research was supported in part by a grant from the National Institute of Health (National Institute of Aging) Grant P01 AG17211 under the auspices of the Center for Research and Education on Aging and Technology Enhancement (CREATE). I would also like to thank Dr. Arthur D. Fisk and Dr. Wendy A. Rogers, in particular, for their guidance and support. A special thanks to Dr. Fredda Blanchard-Fields for her expertise early on in the project as well as her excitement but who passed away before seeing the study's completion. I am very grateful for Dr. Gregory M. Corso for his pragmatic advice and his willingness to serve on my committee. I would also like express my appreciation for the members of the Human Factors and Aging Laboratory, as well as my family and friends for all their help and understanding.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

As technology advances, robots and virtual agents will be introduced into the home and healthcare settings to assist individuals with everyday living tasks. As a result, agents will frequently interact with humans. Thus, understanding how human users interact with and perceive agents is imperative to consider, especially in social interactions.

Personality is important for social interaction. One type of personality cue is emotion displayed through facial expressions (Ekman, Friesen, & Ellsworth, 1982). However, older and younger adults do not recognize emotive facial expressions in other humans in the same way (see Ruffman, Henry, Livingstone, & Phillips, 2008 for a meta-analysis of recent findings). For example, older adults have been found to label negative emotions (e.g., anger, fear, and sadness) differently than younger adults.

Traditionally, studies have investigated how humans label emotive facial expressions based upon static pictures, but this is not reflective of everyday interactions. The few studies that have compared emotion recognition for static and dynamic facial expressions have found evidence for a dynamic advantage, or increased recognition of emotion when viewing a human or synthetic human face in motion versus a static picture. This dynamic advantage has been found when adults viewed human and synthetic human faces (Ambadar et al., 2005; Bould & Morris, 2008; Bould, Morris, & Wink, 2008; Wehrle et al., 2000). One aim in this study was to explicitly investigate if the dynamic advantage for recognizing emotion extends to a virtual agent's face.

This study was designed to examine the effect of motion on younger and older adults' recognition of emotive facial expressions displayed by a virtual agent (i.e., the Virtual iCat). Contrary to the dynamic advantage found in emotion recognition for human faces, older adults had higher proportion match for static virtual agent faces than dynamic ones. Motion condition did not influence younger adults' emotion recognition. For both age groups, the pattern of emotion attributions was no different between motion conditions. Additionally, both age groups had lower proportion match for low Expression Intensities than high Expression Intensities.

Younger adults had higher proportion match than older adults for the emotions of anger, fear, disgust, happiness, and sadness. There were no age-related differences in proportion match for surprise, which younger and older adults often misattributed as fear. Low intensities of emotions were frequently misattributed as neutral. For high expression intensities, happiness was misattributed the least whereas anger was misattributed the most by both younger and older adults. Younger adults commonly misattributed anger with disgust. Older adults misattributed anger as sadness, neutral, or disgust.

There are several theoretical accounts (e.g., the positivity effect, age-related cognitive decline, neuropsychological changes) that attempt to explain various age-related differences in emotion recognition for human faces. However, none of these explanations fully accounted for the age-related differences in this study for emotion recognition. One promising account considered in this study is feature discrimination. In this study, similarity of the position of facial features during emotion expressions was found to provide a plausible explanation for common misattributions demonstrated by younger adults, but less so for older adults. However, further research is needed to explore this explanation.

The results from this study support age-related differences in emotion recognition for virtual agent faces. In contrast, this study did not support the dynamic advantage for virtual agent faces. However, this is a pioneering study evaluating the effect of motion and age on recognizing emotion displayed by a virtual agent's face. Given the findings from this study, designers should consider age-related differences, motion, emotion expression, and intensity when designing agents.

CHAPTER 1

INTRODUCTION

With advancing technology, robots and virtual agents have the ability to move from traditional tool-like applications used by the military and manufacturers to home and healthcare settings. While agents in traditional applications may perform difficult and important work in place of a human, they are not designed to interact with humans on a social level. These agents often lack the naturalistic behavior and appropriate emotions that people expect from robots designed to interact with people (Goetz, Kiesler, & Powers, 2003). Considering that agents in the home and healthcare settings will interact closely with humans, the agent's social characteristics are critical to examine to facilitate successful human-agent interaction.

An agent is essentially "anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors" (Russell & Norvig, 1995, p. 33). Although widely used, the definition of an agent is not agreed upon. Agents may be classified into two basic categories: robots and virtual agents. A robot is a programmable system that is embodied in the physical world (Bartneck et al., 2004) and manipulates its environment using its sensors, memory, computational apparatus, and moving parts (Sheridan, 1992). On the other hand, a virtual agent is a two-dimensional or three-dimensional characterization embodied on a display device (e.g., a computer screen).

Intelligent Agents

"The question is not whether intelligent machines can have any emotions, but whether machines can be intelligent without any emotions" (Minsky, 1988, p. 163). Although many systems could be classified as an agent from Russell and Norvig's (1995) definition, an intelligent agent is a hardware or a software based computational system that is autonomous, proactive, reactive, and has social ability (Wooldridge & Jennings, 1995). That is, an intelligent agent must be able to actively decide for itself what actions to perform in a timely manner and, if appropriate, how to communicate these actions to humans or other agents.

An intelligent agent makes decisions based on its perceptions of its environment (e.g., social, physical) in the context of their end goals. It is not just passively observing and reacting to the environment; it is proactive. Worth highlighting is that agents must have social ability, or the capability of effectively communicating to other agents or humans (Wooldridge & Jennings, 1995). See Franklin and Graesser (1996) for a more complete review of the different taxonomies of agents.

Home Application of Intelligent Agents

As technology advances, the number and types of applications for agents will only increase. One promising application is for a robot or virtual agent to assist people, especially older adults, with everyday living tasks such as helping older adults get out of bed, communicate with their doctor or family, remember to take medication, feed themselves, play games, and read (Smarr, Fausset, & Rogers, 2011). Agents are capable of helping not only with mobility issues and with cognitive environmental support, but they can also serve as social companions. For example, the Bandit-II is a socially assistive robot that proactively encourages cognitive engagement and companionable social interaction with humans by playing music, reading/reciting books and newspapers, and playing games.

Studies have reported that humans do develop relationships with agents, which are often facilitated by an intelligent agent imitating human-human social interactions and personalities (Kanda & Ishiguro, 2006). Even minimal cues of personality by technology can elicit people to respond to it as if it were another human (Nass et al., 1995). Thus, personality can be a powerful tool to provide prompts for complex social behavior between agents and humans (Nass et al.).

One of the most important ways to convey personality is emotion displayed by facial expressions (Ekman, Friesen, & Ellsworth, 1982). Emotions are crucial for natural human-agent interaction. Although agents could be programmed to verbalize their emotions (e.g., saying "I'm sad"), the basic emotive facial expressions may be an efficient, universal way that agents could communicate (e.g., expression of sadness to convey that the agent did not understand a command). Additionally, if an agent does not express emotions, it may be perceived as unapproachable or indifferent to human interaction (Bartneck et al., 2004). Humans may choose to avoid agents lacking emotion or perceived as expressing inappropriate emotion. The focus of this research concerns how humans interpret emotions displayed through facial expressions because they are a critical component in facilitating successful social interaction between agents and humans.

Age-related Differences in Emotion Recognition

Older and younger adults do not label emotions the same way (Isaacowitz et al., 2007; Ruffman, Henry, Livingstone, & Phillips, 2008). Emotion recognition has been the topic of a considerable amount of research because it is a key element in social interaction. With agents being placed in the home, social interactions are not confined to those between humans but are now extended to those between human and agent. Failure of communication is likely to occur if the agent's expression is misinterpreted (Bartneck, 2001).

Most previous studies examining emotion recognition referred to the construct of emotion recognition in terms of accuracy, or proportion correct. In the current study, emotion recognition is defined as the *match* between the participant's label of a facial expression and the designer's intention of the facial expression (i.e., the higher the proportion of match, the greater the emotion recognition). This construct of match emphasizes that the users – both younger and older adults – are not wrong in their recognition and selection of an emotive expression; the facial expression that they perceive may not be the same as what the agent's designer intended. However, it is important to note there may be a variety of reasons as to why participants report a certain emotion.

In a recent summary of the literature, Isaacowitz et al. (2007) calculated the percentages of studies with significant age group differences in recognizing emotion. This summary of the literature found older adults were worse at labeling negative emotion. Specifically, 83% of studies demonstrated an age-related difference in labeling anger, 71% for sadness, and 55% for fear (Isaacowitz et al.). No consistent differences between the age groups were found for happy, surprise, and disgust.

Ruffman and colleagues (2008) performed a meta-analysis on the last 20 years of research on the age-related differences in emotion recognition in humans. Similar to Isaacowitz et al.'s (2007) results, Ruffman et al. found older adults were worse than younger adults at labeling the negative emotions of anger and sadness followed by fear. Older adults were also worse than younger adults at labeling expressions of happy and surprise. However, younger adults were not better than older adults in recognizing all emotions. Younger adults were worse at recognizing disgust as compared to older adults, but the difference was not statistically significant.

Why these changes occur is not yet thoroughly understood. However, some of the more prominent schools of thought posit that these differences are due to a positivity effect, age-related cognitive decline, or neuropsychological changes over the lifespan. Also, the similarity of the features among the facial features is a promising explanation to account for age-related differences in emotion recognition.

Positivity Effect

The positivity effect, or sometimes called the positivity bias, postulates that older adults remember, attend, and behave in ways that favor positive information over negative information (Carstensen & Mikels, 2005). This may represent an adaptive strategy for older adults to avoid social conflict and maintain emotion regulation (Carstensen & Mikels). For example, when pictures of facial expressions are shown in pairs, older adults tend to focus on happy expressions more than negative ones such as anger and sadness (Mather & Carstensen, 2003).

When presented with a negative expression, older adults may also try to maintain their emotions by attending to less threatening regions of the face. Research has shown that older adults look at and attend to different areas of the face than younger adults (Sullivan, Ruffman, & Hutton, 2007; Wong, Cronin-Golomb, & Neargarder, 2005). Young adults tend to focus more on the information from the top half of the face, particularly the eye regions, of a negative expression, whereas older adults spend more time looking at the bottom half of the face, especially the mouth regions (Sullivan et al.; Wong et al.). This seems counterproductive because recognition of the negative emotions anger, fear (Sullivan et al.), and sadness are adversely affected by focusing on the bottom half of the face (Calder, Keane, Young, & Deane, 2000; Wong et al.).

Of the six basic emotions, the positivity effect would predict that older adults would clearly recognize the only unambiguously positive emotion (i.e., happy) while being worse at identifying the unambiguously negative emotions (i.e., sadness, disgust, anger, fear). Somewhere in the middle is surprise because it is sometimes considered positive and other times regarded as negative. In contradiction to theory, a meta-analysis of the emotion recognition literature has found older adults to be better at recognizing disgust, which is a negative emotion (Ruffman et al., 2008).

Age-related Cognitive Decline

As individuals age, their perceptual and cognitive abilities change. Declines in perceptual speed, working memory capacity (Phillips & Henry, 2005), and fluid ability (Salthouse, 1992) have been associated with age. As a cognitive task becomes more demanding, age-related differences tend to increase (e.g., McDowd & Craik, 1988; Verhaeghen & Cerella, 2002). According to this perspective, if age-related differences in emotion identification reflect more general cognitive decline, then more intricate emotions would be more difficult to identify as we age. Therefore, if the generalized cognitive decline account is true, then the most difficult emotions to perceive would be the same for young adults and older adults, even if the level of recognition differs.

Relative to other emotions, younger adults were least accurate in identifying fear (mean accuracy = 79%), followed by disgust (81%), anger (86%), surprise (87%), sadness (89%), and happiness (98%) (Ruffman et al., 2008). As fear, disgust, and anger were least accurately identified emotions by younger adults, then they should also be the least accurately identified emotions by older adults. However, this is not found consistently in the literature. For example, older adults are better at recognizing disgust, surprise, and happiness than labeling anger, sadness, and fear out of all the emotions being studied (Ruffman et al.). Even after controlling for individual differences in fluid intelligence, face processing, and visual perception of faces, age-related decrements in recognizing fear and sadness were found (Sullivan & Ruffman, 2004).

Neuropsychological Changes

Some argue that the pattern of age changes within neural systems may be related to that of age-related differences in identifying emotions (Calder et al., 2003; Isaacowitz et al., 2007; Ruffman et al., 2008; Sullivan & Ruffman, 2004; Wong et al., 2005). Many neural systems are involved in labeling facial expressions of emotion, but primarily this process involves the frontal and temporal systems. Although the brain undergoes a widespread gradual atrophy, these frontal and temporal areas degrade more rapidly (e.g., Raz et al., 1997). Age-related changes in the neural system may negatively influence emotion recognition.

Feature Discrimination: Similarity of Expression Features

The recognition of emotions is influenced by both configural and featural processing of human facial expressions (McKelvie, 1995). The arrangement of the features of the face (e.g., mouth, eyebrows, eyelids) influences processing of the face both holistically and by its individual features to some degree (McKelvie, 1995). In a recent unpublished thesis, Beer (2010) computed a similarity index between corresponding facial features for a pair of different emotive expressions displayed by a virtual agent. This was repeated for all features of the agent's face for all possible pairs of five facial expressions (angry, happy, fear, sad, neutral) made by a virtual agent. The findings supported, in part, the idea that age-related differences in emotion recognition may be due to how similar the placement of the features are.

Motion and Emotion Recognition: The Dynamic Advantage

Most emotion recognition research has used static photographs, like Ekman and Friesen's (1976) pictures of facial affect stimuli; few studies have focused on manipulating the dynamic formation of emotion and how that influences older adults' recognition of emotions. Static pictures do not represent interactions in daily life because they are devoid of motion and often depict highly intense facial expressions (Caroll & Russell, 1997). Although facial expressions vary in intensity in day-to-day living, they are usually subtle (Ekman, 2003) and seeing emotions in motion may facilitate recognition of facial expressions at more subtle levels.

Research with younger and middle-aged adults (Ambadar, Schooler, & Cohn, 2005; Bould & Morris, 2008; Bould, Morris, & Wink, 2008; Wehrle, Kaiser, Schmidt, &

Scherer, 2000) has shown there to be an overall advantage of viewing the dynamic formation of emotion over static picture conditions. However, this dynamic advantage was attenuated with expressions of higher intensity (Bould & Morris).

Bould and Morris (2008) found that young adults had higher recognition of emotions when viewing the dynamic formation of emotions as opposed to seeing a single static picture or several static pictures in sequence (multi-static condition). The multi-static condition contained the same amount of frames as the dynamic condition but had a mask between each frame to remove the perception of motion. Their findings as well as others suggest some aspect of motion aids emotion recognition more than viewing the same number of static frames in sequence (Ambadar et al., 2005; Bould & Morris).

Adding this motion information may help individuals, especially older adults, to recognize emotion expressions at more subtle intensities. In particular, older adults have been shown in laboratory studies to have difficulty identifying anger, sadness, and fear from static pictures (Ruffman et al., 2008). Showing the dynamic formation of emotion is more reflective of emotion expression formation in daily life, which older adults are more familiar with than the static faces in the laboratory. Motion could provide some additional information potentially making emotions less ambiguous.

Overview of Study

The literature has shown evidence for the importance of social cues, especially emotion, in interactions between agents and humans. Nevertheless, research on how people interpret these social properties expressed by agents is still in its inception stages. In particular, the problem regarding how recognition of (or at least the reporting of) emotion expressed by agents needs further research. In all likelihood, there will be a high demand for robots and virtual agents to assist the growing older adult population. Thus, it is important to investigate whether age-related differences in emotion recognition of human faces translate to that of agents. Perhaps more important, evaluation of recognition of emotion portrayed by humanoid agents is an important crucible for testing theory of emotion recognition.

As previously discussed, there is strong evidence for age-related differences in labeling emotion displayed by humans. Beer, Fisk, and Rogers (2009; 2010) found age-related deficits in emotion recognition with static pictures of a virtual agent, but do these deficits still exist if people can see the dynamic formation of the emotion? In the current study, I investigated the dynamic formation of emotive facial expressions displayed by a virtual agent, which contains information additional to static pictures (Bould, Morris, & Wink, 2008). Whether age-related differences in emotion recognition will translate to agents is just beginning to be explored.

This study was designed to assess the effects of age, motion, emotion, and expression intensity on emotion recognition. Previous research with human and synthetic human faces has provided evidence of a dynamic advantage, or increased recognition of emotion when viewing a face in motion versus a static picture (Ambadar et al., 2005; Bould & Morris, 2008; Bould, Morris, & Wink, 2008; Wehrle et al., 2000). The current study extended the investigation of the dynamic advantage found with human faces to that of virtual agents. More specifically, the following questions were addressed: (1) does motion influence emotion recognition of a virtual agent's facial expression?; and (2) are there age-related differences in emotion recognition of a virtual agent's facial expression?

To address these questions, younger and older adults were randomly assigned to one of two motion conditions. In the dynamic condition, participants viewed brief videos of a virtual agent's dynamic formation of an emotional expression from neutral. In the static condition, participants viewed the still picture of an expression. The emotional expressions were anger, fear, disgust, happiness, sadness, and surprise. Each emotion expression was presented at five different emotion intensities (20%, 40%, 60%, 80%, and 100%). At the end of each stimulus presentation, participants selected which facial expression (anger, fear, disgust, happiness, sadness, surprise, or neutral) they thought the virtual agent displayed.

CHAPTER 2

METHOD

Participants

Thirty-one younger adults aged 18-26 years old participated in this study (M = 19.87, SD = 1.93, 14 males). They were recruited from the Georgia Institute of Technology School of Psychology undergraduate participant pool and compensated with course credit (the exact value of the credit is determined by the student's course instructor). Twenty-nine community-dwelling older adults aged 65-85 years old participated as well (M = 73.97, SD = 4.28, 16 males). They were recruited from the Atlanta metropolitan area using the Human Factors and Aging Laboratory participant database. Older adults were compensated with $30. All participants had 20/40 or better visual acuity for near and far vision (corrected or uncorrected). Due to recruitment logistics, the older adult participants had prior experience with the virtual agent (Beer, 2010); this experience was one year or more prior to participating in the present study. The younger adults, however, reported no prior experience with the agent.

All participants completed eight ability tests: the Snellen Eye chart (Snellen 1868), Reverse Digit Span (Wechsler, 1997), Digit Symbol Substitution (Wechsler), Shipley Institute of Living vocabulary scale (Shipley, 1986), Benton Facial Discrimination Test-short form (Levin, Hamsher & Benton, 1975), and simple and choice reaction time tests (locally developed).

Table 1 depicts the means and standard deviations for the ability tests as well as demographic data for each Motion Condition within each age group. No significant differences were found between Motion Conditions within either age group ($ps > .26$).

There were statistically significant differences between the age groups in self-reported health, cognitive abilities, response time, and education level (Table 1). Self-ratings of health were significantly higher for younger adults than older adults ($F(1,56) = 4.57$, $p = .04$, $\eta_p^2 = .08$). Younger adults outperformed older adults on the Reverse Digit Span ($F(1,56) = 11.36$, $p = .001$, $\eta_p^2 = .17$), Digit Symbol Substitution ($F(1,56) = 72.87$, $p < .001$, $\eta_p^2 = .57$), and simple ($F(1,56) = 17.79$, $p < .001$, $\eta_p^2 = .24$) and choice response time measures ($F(1,56) = 33.14$, $p < .001$, $\eta_p^2 = .37$). However, older adults outperformed younger adults on the Shipley vocabulary test ($F(1,56) = 34.06$, $p < .001$, $\eta_p^2 = .38$). Older adults were also significantly more educated ($F(1,56) = 9.98$, $p < .01$, $\eta_p^2 = .15$). There were no age-related differences for the Benton Facial Discrimination Test ($p = .15$). These data were consistent with previous research (Czaja et al., 2006; Benton, Eslinger, & Damasio, 1981) and all participants' ability scores were within the expected range for their age group.

Table 1

Demographic and ability data for younger and older adults

	Dynamic Condition	Static Condition	Overall
Younger adults			
Age	19.69 (1.92)	20.07 (1.98)	19.87 (1.93)
Education[a]	62.50%	46.67%	54.84%
Health[b]	4.06 (0.77)	3.80 (.56)	3.94 (0.68)
Health compared to others[b]	3.94 (0.85)	3.60 (0.63)	3.77 (0.76)
Reverse Digit Span[c]	9.44 (2.71)	8.93 (2.46)	9.19 (2.56)
Digit Symbol Substitution[d]	76.94 (12.07)	77.87 (10.45)	77.39 (11.14)
Shipley Vocabulary[e]	30.19 (3.73)	29.67 (3.68)	29.94 (3.65)
Benton Facial Discrimination[f]	48.38 (2.28)	47.93 (3.41)	48.16 (2.83)
Simple Response Time[g]	299.49 (82.06)	297.24 (44.02)	298.40 (65.36)
Choice Response Time[h]	316.63 (43.31)	324.80 (36.48)	320.58 (39.70)
Older adults			
Age	73.60 (3.72)	74.36 (4.92)	73.97 (4.28)
Education[a]	86.67%	71.43%	79.31%
Health[b]	3.40 (1.06)	3.57 (0.76)	3.48 (0.91)
Health compared to others[b]	3.67 (1.11)	3.64 (0.75)	3.66 (0.94)
Reverse Digit Span[c]	7.07 (2.28)	7.00 (2.39)	7.03 (2.29)
Digit Symbol Substitution[d]	54.53 (10.08)	49.71 (13.04)	52.21 (11.65)
Shipley Vocabulary[e]	34.67 (2.53)	35.36 (3.39)	35.00 (2.94)
Benton Facial Discrimination[f]	45.80 (2.49)	48.07 (4.36)	46.90 (3.64)
Simple Response Time[g]	401.20 (151.59)	456.49 (164.60)	427.89 (157.67)
Choice Response Time[h]	428.67 (94.72)	471.21 (138.65)	449.21 (117.81)

Note: Each cell contains the mean followed by the standard deviation in parentheses except for education. [a] Percentage of participants with some college education and above. [b] 1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent. [c] Memory span (Weschler, 1997); score was total correct for the 14 sets of digits presented. [d] Perceptual speed (Weschler, 1997); score was total number correct of 100 items. [e] Semantic knowledge, (Shipley, 1986); score was the total number correct from 40. [f] Facial discrimination (Levin, Hamsher & Benton, 1975); score was total number correct converted to 54 point scale. [g] Response time (locally developed); determined by 50 trial test in ms for one hand. [h] Response time (locally developed); determined by 50 trial test in ms for both hands.

Materials/Apparatus

The Philips Virtual iCat is a 2D virtual robotic characterization, which is designed as research platform for human-agent interaction. The Virtual iCat has 11 servo motors that control the individual features of the face like eyes, mouth, and eyebrows. Being equipped as such, the Virtual iCat can produce many different facial expressions such as happy, sad, and angry. All of the iCat expressions were created from the qualitative descriptions provided by Ekman and Friesen (1975; 2003). The expressions of anger, fear, happy, sad, and neutral were created by Beer (2010) whereas surprise and disgust were created specifically for this study.

Each emotive facial expression was shown at increments along a continuum of intensity. The intensity level was in 20% increments from neutral (e.g., no expression of emotion) to extreme (e.g., the angriest face the Virtual iCat can make). The Virtual iCat displayed six different emotive facial expressions: anger, fear, disgust, happiness, sadness, and surprise. The different intensities were fashioned by linear interpolation of the servo positions in 20% increments from neutral (0%) to extreme emotion (100%). Figure 1 contains pictures of the Virtual iCat's facial expressions for 60% intensity.

Each participant saw 30 different emotive facial expressions (6 emotions x 5 intensities). Each of the 30 videos or pictures were presented pseudo-randomly (no more than two of the same emotion presented consecutively) within a block of trials. There were four blocks of 30 trials for a grand total of 120 trials.

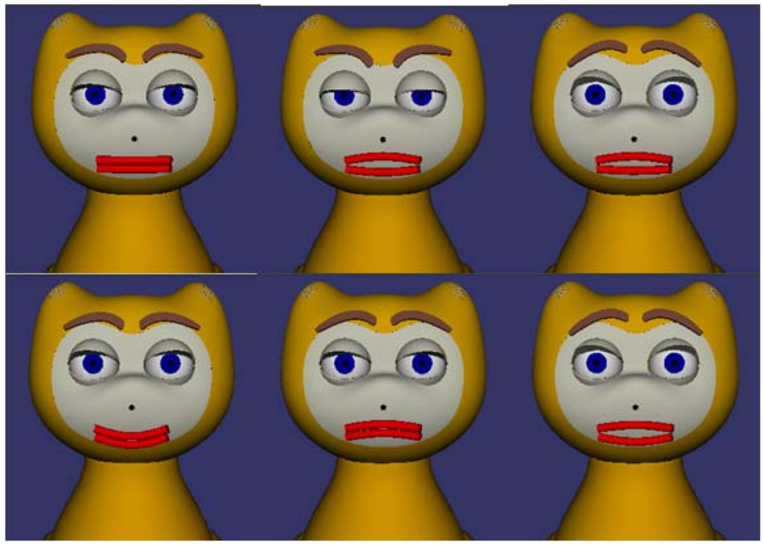

Figure 1. The Virtual iCat displaying the expressions of anger, disgust, fear, happiness, sadness, and surprise at 60% intensity. The expressions of disgust and surprise were created for this study whereas the other four expressions were created by Beer (2010).

Dynamic Condition

For a given trial in the dynamic condition, a participant was shown a 3.25 second video of the Virtual iCat transitioning from neutral to one of the 30 expressions (e.g., neutral to 80% happy). The first three seconds of the video showed the iCat transitioning and the last 0.25 seconds of the video showed the final expression.

Because each video shows the formation of an emotive expression from a neutral expression, the lack of change in a video of the iCat transitioning from neutral to neutral would have been obvious. Thus, there were no neutral videos. However, neutral was a response that a participant could choose, because the lower intensities of the emotive facial expressions may have been perceived as lacking emotion, or neutral.

Static Condition

The static condition was the same as the dynamic condition except that participants saw a still picture of the emotive facial expression for 3.25 seconds instead of a video displaying the dynamic formation of the expression.

Displaying Stimuli

Philips' Open Platform for Personal Robotics (OPPR) software was used to create each expression by manipulating individual servos of the Virtual iCat's face. E-Prime was used to develop a software program to display the expressions to participants (Psychology Software Tools, Pittsburgh, PA). Dell Optiplex 760 computers with 20-inch monitors displaying 1280 x 1024 pixels in 32 bit color were used to run the software program. All textual instructions on the computer screen were displayed in 18 point font size. The software program displayed the stimuli as approximately 631 x 636 pixels in size. Participants were seated approximately 25 inches from the computer monitor. The stimuli were 7.4 inches in width by 7.45 inches in height subtending a visual angle of approximately 17 degrees.

A QWERTY keyboard was used for participants to indicate their responses by pressing a key. The participant pressed one of seven numeric keys (`, 2, 4, 6, 8, 0, =) that corresponded to and were labeled with anger, fear, disgust, happiness, sadness, surprise, and neutral. The participant's response and response time (RT) in milliseconds were recorded.

Ability Tests and Questionnaires

The following abilities tests were used to describe the sampled population: the Snellen Eye chart – visual acuity (Snellen 1868), Reverse Digit Span – memory (Wechsler, 1997), Digit Symbol Substitution – perceptual speed (Wechsler), Shipley Institute of Living vocabulary scale – semantic knowledge (Shipley, 1986), Benton Facial Discrimination Test-short form – facial discrimination (Levin, Hamsher & Benton, 1975), and simple and choice response time tests – response time (locally developed).

Participants completed a demographic and health questionnaire (adopted from Czaja et al., 2006). It collected data such as information on age, education, current health status, and medication regimen (Appendix A). They also completed an agents and emotion questionnaire which consisted of six sections of answers and Likert scales assessing previous experience with agents as well as the importance of individual facial features for identifying emotions (Appendix B).

Design

The four independent variables included: (1) Age (younger and older adults) as a grouping variable; (2) Motion Condition (dynamic and static) as a between-subjects variable; (3) Emotion Expression (anger, fear, disgust, happiness, sadness, and surprise) as a within-subjects variable; and (4) Expression Intensity (20%, 40%, 60%, 80%, and 100%) as a within-subjects variable. The dependent variables were response time (msec) and mean proportion match, which is the mean proportion of participant responses that match the emotion the Virtual iCat was designed to show.

Procedure

Consent, Background, and Ability

Participants were treated in accordance with APA ethical requirements. After providing informed consent, the participant completed a demographics and health questionnaire (adopted from Czaja et al., 2006; Appendix A). Participants then completed the following ability tests: Snellen Vision (Snellen, 1868), Reverse Digit Span (Wechsler, 1997), Digit Symbol Substitution (Wechsler), Shipley Institute of Living vocabulary scale (Shipley, 1986), Benton Face Recognition Matching Task (Levin, Hamsher, & Benton, 1975) and simple and choice response time tests (locally developed). Participants were offered a short break before beginning practice.

Practice

Practice was divided into three parts. First, to familiarize the participants with the response keys, they were shown the text label of an emotion (e.g., “disgust”) and were required to press the correspondingly labeled key. Participants were able to practice correctly matching the text label of an emotion and its response key. A given practice trial terminated when the label and response key were *correctly* matched. Each emotion and neutral was presented six times for a total of 42 practice trials.

Second, to help participants get accustomed to the Virtual iCat's appearance, they were shown a static picture of it displaying a neutral expression. Participants had as much time as they needed to examine the picture. The second part of practice terminated when the participant pressed the "enter" key.

The last practice task allowed participants to become familiar with the sequencing of an experimental trial. Depending on random assignment, a participant saw either dynamic videos or static pictures of the Virtual iCat for 3.25 seconds. The participant had up to 27 seconds to respond by pressing the labeled key that matched the facial expression he or she perceived from the Virtual iCat's face. Participants were instructed that their interpretation of the facial expression was more important than the time it takes for them to make a response. The experimenter guided each participant through two practice trials (neutral to 100% happy, neutral to 40% happy).

Experimental Trials

The experimental trials began after a participant finished the three practice tasks. Each participant completed 120 experimental trials. The experimental trials were presented to each participant in four blocks of 30 pseudo-randomly ordered videos (no more than two of the same Emotion Expression presented consecutively).

Each trial began by pressing the spacebar key which was followed immediately by a fixation cross centered on the monitor for one second and either a video or static picture of an iCat expression for 3.25 seconds (depending on random assignment). Key responses were not valid or registered while a video or picture was on the screen. The video or picture disappeared after 3.25 seconds and the participant was immediately prompted to select an emotion by the question, "Which Emotion?" to the right of the picture. The participant had up to 27 seconds to make a response using the keys labeled with the emotion he or she thought the iCat was displaying. Once a response was made or 27 seconds elapsed without a response, the trial terminated. A screen prompting the participant to press the spacebar to begin the next trial was shown. All 30 facial expressions were represented in each block of trials. Participants were offered a break at the mid-way point during a block (after 15 trials) and between blocks (after 30 trials).

Post Experimental Trials

After completing all the experimental trials, participants completed a questionnaire designed to assess their experience with agents and the strategies they used to identify certain emotions (Appendix B). Lastly, the participant was debriefed and compensated.

CHAPTER 3

RESULTS

Overview of Analyses

Unless noted otherwise, alpha was set at $p < .05$ for all statistical tests, and all t-test analyses were two-tailed. Also, all error bars represent standard error of the mean. Huyhn-Feldt and Bonferroni corrections were used when appropriate.

Response time data were collected, but the participants were instructed to consider the time to make a response secondary to their judgment of emotion. Thus, response time is not a traditional chronometric measure of mental processes (Posner, 1978). The analyses and figures for response time during correct trials are provided in Appendices C-D.

The analyses presented below were conducted using each participant's *proportion match*. The proportion match score represents the proportion of responses matching the iCat's emotion as designed for the experiment.

Omnibus Analysis of Emotion Recognition

The effects of Emotion Expression, Motion Condition, Expression Intensity and Age on emotion recognition were analyzed via a 2 (Age) x 2 (Motion Condition) x 6 (Emotion Expression) x 5 (Expression Intensity) mixed-design analysis of variance (ANOVA). Age was a grouping variable. Motion Condition was a between-subjects variable. Emotion Expression and Expression Intensity were within-subjects variables. The dependent variable was proportion match.

The 4-way interaction ($F(17.26,966.59) = 0.72$, $p = .78$, $\eta_p^2 = .01$), the Age x Motion Condition x Emotion Expression interaction ($F(4.81,269.47) = 0.88$, $p = .49$, η_p^2

= .02), and the Age x Motion Condition interaction ($F(1,56) = 2.58$, $p = .11$, $\eta_p^2 = .04$) were not statistically significant. All other interactions and main effects were statistically significant. The statistics for the 4-way ANOVA are provided in Appendix E. Detailed below are analyses further exploring the statistically significant interactive effects.

Effects of Motion on Emotion Recognition

In this section of results, the analyses of Motion Condition, Expression Intensity, and Emotion Expression on emotion proportion match are presented first, followed by analyses for age-related differences in proportion for Motion Condition and Expression Intensity. Lastly, patterns of attributions for younger and older adults for Motion Condition and Expression Intensity are presented.

Motion, Intensity, and Expression Effects on Recognizing Emotion

To better understand the influence of motion, emotion, and intensity on emotion recognition, a separate Motion Condition x Expression Intensity ANOVA was conducted for each Emotion Expression. These analyses combined age groups.

There was a significant main effect of Motion Condition for disgust ($F(1,58) = 5.12$, $p = .03$, $\eta_p^2 = .08$), but not for any other Emotion Expressions. Participants in the static condition were better at recognizing disgust than those in the dynamic condition. Moreover, participants had similar proportion match for recognizing anger, fear, happiness, sadness, and surprise for the dynamic condition than in the static condition (Appendix F). There was a main effect of Expression Intensity for all six Emotion Expressions. These data suggest that emotion recognition was worse for lower Expression Intensities than higher intensities (Appendices M-R contain details).

The interactions of Motion Condition and Expression Intensity were statistically significant for disgust ($F(4,232) = 3.03$, $p = .02$, $\eta_p^2 = .05$), and surprise ($F(3.50,203.17) = 12.24$, $p < .001$, $\eta_p^2 = .17$). Appendices G-H contains more details on these significant interactions. To better understand these interactions, simple main effects analyses were conducted for disgust and surprise.

Interaction of Motion and Intensity for Disgust

To further investigate the statistically significant Motion Condition x Expression Intensity interaction for disgust, a simple main effects analysis was conducted. First, separate independent t-tests compared dynamic and static conditions for each Expression Intensity. Emotion recognition was statistically lower for participants in the dynamic condition than in the static condition for 80% Expression Intensity ($t(58) = -3.03$, $p = .004$). No other t-tests were statistically significant. These findings indicate that participants were worse at recognizing disgust at 80% Expression Intensity in the dynamic condition than in the static condition (Figure 2).

Second, a set of 10 paired t-tests were conducted separately for the dynamic condition and the static condition. The t-tests compared proportion match between all possible pairs of Expression Intensities. Appendix G contains statistics for each set of paired t-tests. The pattern of proportion match was similar in both Motion Conditions. Participants had statistically lower proportion match for the 20% Expression Intensity than the 40%, 60%, 80% and 100% intensities. There was no statistical difference in emotion recognition among the higher intensities of disgust. These data suggest that participants had lower proportion match when labeling disgust at lower intensities than higher intensities.

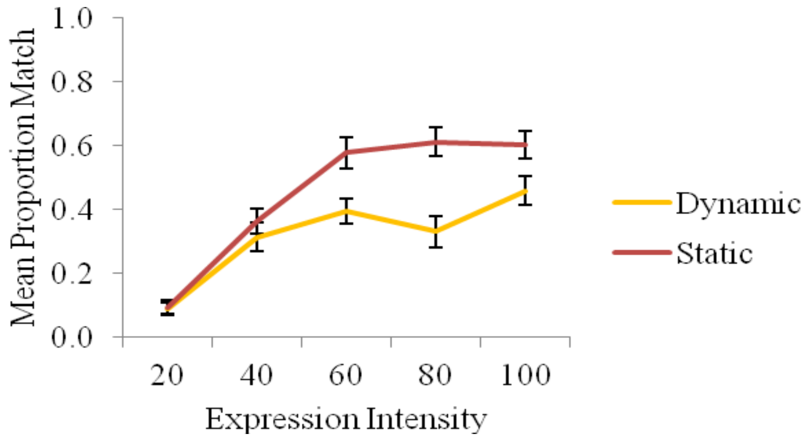

Figure 2. Participants' mean proportion match at different intensities of disgust in the dynamic and static conditions.

<u>Interaction of Motion and Intensity for Surprise</u>

To further examine the statistically significant Motion Condition x Expression Intensity interaction for surprise, a simple main effects analysis was conducted. First, an independent t-test comparing proportion match between the dynamic and static conditions was performed for each Expression Intensity. Participants in the dynamic condition had significantly lower proportion match than those in the static condition for 80% ($t(58) = -3.71$, $p < .001$) and 100% ($t(58) = -3.52$, $p = .001$) Expression Intensities. Participants' proportion match did not differ significantly between the two Motion Conditions for the remaining intensities: 20% ($t(58) = 0.89$, $p = .38$), 40% ($t(49.55) = -3.52$, $p = .25$), and 60% ($t(58) = -2.10$, $p = .04$). Participants in the dynamic condition had lower proportion match when labeling 80% and 100% intensities of surprise than those in the static condition (Figure 3).

Second, a set of 10 paired t-tests comparing all possible pairs of Expression Intensity were performed separately for the dynamic condition and the static condition (Appendix H contains details of these t-tests). In the dynamic condition, none of the t-tests were statistically significant. This suggests that participants' proportion match was similar for all intensities of surprise in the dynamic condition. In the static condition, proportion match was significantly lower for 20% Expression Intensity than all higher intensities. None of the other t-tests were significant. These data indicate that proportion match was lower for the 20% intensity of surprise than any higher intensity.

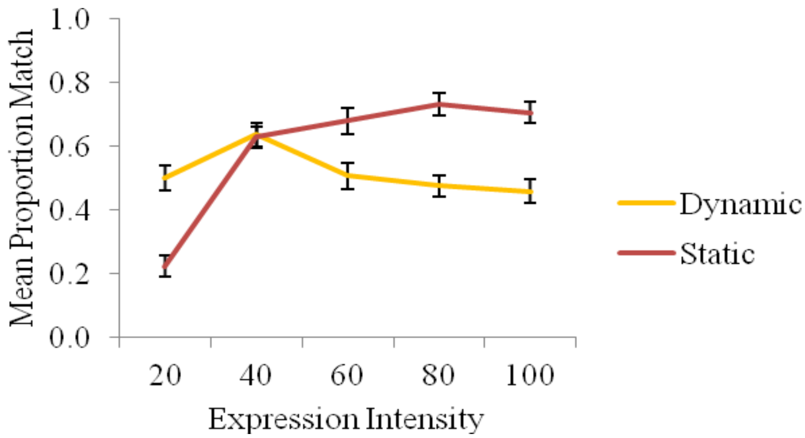

Figure 3. Participants' mean proportion match at different intensities of surprise in the dynamic and static conditions.

Motion, Intensity, and Age-related Differences Recognizing Emotion

To investigate how emotion recognition differed as a function of age, motion, and intensity, separate Motion Condition x Expression Intensity ANOVAs were conducted for younger adults and older adults. All six Emotion Expressions were combined for these analyses.

<u>Motion and Intensity Effects on Younger Adults</u>

The main effect of Expression Intensity was statistically significant ($F(4,116) = 156.99$, $p < .001$, $\eta_p^2 = .84$). Ten paired t-tests were conducted to further examine the main effect of Expression Intensity (see Appendix I for details). Proportion match was statistically lower for 20% and 40% Expression Intensity than all higher levels of Expression Intensity. Emotion recognition did not statistically differ among higher

Expression Intensities (i.e., 60%, 80%, and 100%). Younger adults had lower proportion match at lower Expression Intensities than higher intensities.

The main effect of Motion Condition ($F(1,29) = 0.40$, $p = 0.53$, $\eta_p^2 = .01$) and the Expression Intensity x Motion Condition interaction were not statistically significant ($F(4,116) = 0.36$, $p = .84$, $\eta_p^2 = .01$). These data indicate that younger adults had similar levels of proportion match in the dynamic and static conditions.

Motion and Intensity Effects on Older Adults

There was a main effect of Motion Condition ($F(1,27) = 5.08$, $p = .03$, $\eta_p^2 = .16$) with older adults' proportion match significantly lower in the dynamic condition than in the static condition. A main effect of Expression Intensity was found ($F(3.03,81.67) = 48.92$, $p < .001$, $\eta_p^2 = .64$), suggesting that older adults' proportion match varied among the levels of intensity. Ten paired t-tests were conducted to examine the main effect of Expression Intensity (see Appendix J for details). Proportion match for older adults was significantly lower for 20% and 40% Expression Intensities than higher Expression Intensities. Expression Intensities of 60%, 80% and 100% did not differ statistically from one another in proportion match. Similar to younger adults, older adults had lower proportion match at lower Expression Intensities than higher intensities.

These main effects were qualified by a statistically significant Motion Condition x Expression Intensity interaction ($F(3.03,81.67) = 56.17$, $p = .001$, $\eta_p^2 = .19$). This suggests that older adult emotion recognition depends on both Motion Condition and Expression Intensity. A simple main effects analysis was used to explore this interaction further.

First, an independent t-test compared proportion match of the dynamic condition against that of the static condition for each Expression Intensity. None of the independent t-tests were statistically significant, suggesting that older adults' proportion match was similar between the dynamic and static conditions for each Expression Intensity.

Second, a set of 10 paired t-tests compared all possible pairs of Expression Intensity for each Motion Condition separately (see Appendix J for statistics). In the both motion conditions, older adults had significantly lower proportion match for lower Expression Intensities (e.g., 20% and 40%) than higher intensities (e.g., 60%, 80%, and 100%).

Misattributions of Emotion for Younger and Older Adults for Dynamic and Static Conditions

Attribution matrices were created for the dynamic and static conditions for each age group to assess Emotion Expression misattributions (Tables 2-5). Expression Intensity is combined for these attribution matrices. However, younger adults' and older adults' attributions for low and high Expression Intensities for each motion condition are in Appendices K-L.

The rows in the attribution matrices represent the Emotion Expression displayed by the experimental program, and the columns represent the Emotion Expression selected as a response by participants. Each cell represents the proportion of the total number of trials that a displayed Emotion Expression (rows) was attributed to a selected Emotion Expression (columns). Grey cells are the proportion match, or the total trials that the participants' selection matched the Emotion Expression designed to display.

Younger Adult Misattributions of Dynamic and Static Emotion Expressions

Younger adults in the dynamic and static conditions did not differ in their frequency (proportion match) or pattern of misattributions (Tables 2-3). In both Motion Conditions, younger adults demonstrated fewest misattributions for happiness, followed by sadness. They demonstrated the most misattributions for anger and disgust, which were frequently misattributed with one another or neutral. Younger adults also frequently misattributed surprise and fear with one another.

Table 2

Emotion attributions made by younger adults in the dynamic condition

		Younger Adult Dynamic Condition						
		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.50	0.20	0.00	0.01	0.05	0.01	0.23
	Disgust	0.32	0.44	0.02	0.01	0.02	0.04	0.15
	Fear	0.00	0.02	0.53	0.00	0.04	0.35	0.07
	Happy	0.00	0.00	0.00	0.93	0.01	0.01	0.05
	Sad	0.01	0.04	0.00	0.00	0.76	0.01	0.18
	Surprise	0.01	0.01	0.33	0.01	0.02	0.55	0.07

Table 3

Emotion attributions made by younger adults in the static condition

		Younger Adult Static Condition						
		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.44	0.18	0.01	0.02	0.04	0.00	0.31
	Disgust	0.18	0.54	0.01	0.01	0.05	0.02	0.19
	Fear	0.00	0.02	0.51	0.00	0.08	0.30	0.08
	Happy	0.00	0.00	0.00	0.96	0.01	0.01	0.02
	Sad	0.03	0.03	0.04	0.00	0.77	0.01	0.11
	Surprise	0.00	0.02	0.26	0.00	0.05	0.59	0.08

Older Adult Misattributions of Dynamic and Static Emotion Expressions

Overall, older adults in the dynamic condition made more misattributions (lower proportion match) than those in the static condition (Tables 4-5). However, they did not differ in their patterns of attributions between Motion Conditions. Older adults demonstrated fewest misattributions for happiness in both dynamic and static conditions.

They demonstrated the most misattributions for anger, which were distributed among neutral and sadness. Disgust was frequently misattributed as neutral or sadness. Older adults also frequently misattributed surprise and fear with one another.

Table 4

Emotion attributions made by older adults in the dynamic condition

Older Adult Dynamic Condition

		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.08	0.10	0.03	0.01	0.31	0.01	0.46
	Disgust	0.07	0.22	0.06	0.07	0.30	0.07	0.22
	Fear	0.08	0.02	0.30	0.03	0.02	0.44	0.12
	Happy	0.01	0.03	0.02	0.64	0.08	0.09	0.14
	Sad	0.08	0.14	0.04	0.01	0.42	0.04	0.28
	Surprise	0.07	0.02	0.24	0.12	0.02	0.47	0.07

Table 5

Emotion attributions made by older adults in the static condition

Older Adult Static Condition

		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.09	0.14	0.02	0.01	0.24	0.03	0.47
	Disgust	0.11	0.31	0.05	0.02	0.24	0.05	0.23
	Fear	0.04	0.05	0.22	0.02	0.05	0.45	0.17
	Happy	0.00	0.02	0.02	0.72	0.05	0.08	0.12
	Sad	0.08	0.10	0.05	0.01	0.55	0.06	0.15
	Surprise	0.01	0.02	0.14	0.07	0.03	0.59	0.15

Misattribution of Emotion: Age-related Differences for Motion

Overall, younger adults demonstrated fewer misattributions and higher proportion match than older adults (Tables 2-5). Younger adults in the dynamic and static conditions did not differ in their proportion match or pattern of misattributions. Older adults in the dynamic condition made more misattributions overall than those in the static condition. However, they did not differ in their pattern of misattributions between the Motion Conditions. Both age groups demonstrated fewest misattributions for happiness, and the most misattributions for anger. Compared to younger adults, older adults were more distributed in their misattributions for anger and disgust, which they frequently misattributed as neutral or sadness.

Summary of the Effects of Motion

For the Emotion Expressions of anger, fear, happiness, and sadness, Motion Condition did not statistically affect emotion recognition. However, it did influence disgust and surprise. Combined across age groups, participants in the dynamic condition had lower proportion match for 80% intensity of disgust and surprise, and 100% intensity of surprise than participants in the static condition. Additionally, participants had lower proportion match for disgust and surprise at the lowest Expression Intensity as compared to higher intensities.

Combined across all Emotion Expressions, older adults' proportion match depended on both Motion Condition and Expression Intensity whereas younger adults' proportion match only depended on Expression Intensity. Both age groups were worse at labeling emotion at lower Expression Intensities than higher intensities. Older adults in the static condition made fewer misattributions than those in the dynamic condition. In both Motion Conditions, older adults often labeled anger as neutral or disgust, whereas younger adults labeled anger as disgust. Both age groups frequently labeled fear as surprise, as well as demonstrated fewest misattributions for happiness.

Understanding Age-Related Differences:

The Effects of Emotion and Intensity on Emotion Recognition

To further investigate how emotion recognition differed as a function of age, emotion, and intensity, separate Age x Expression Intensity ANOVAs were conducted for each Emotion Expression. For these analyses, dynamic and static conditions were combined.

Anger

There was a statistically significant main effect of age for anger ($F(1,58) = 77.50$, $p < .001$, $\eta_p^2 = .72$), with younger adults having significantly higher proportion match than older adults. There was also a significant main effect of Expression Intensity ($F(4,232) = 40.38$, $p < .001$, $\eta_p^2 = .41$). Appendix M contains details for younger and older adults' emotion recognition for all Expression Intensities of anger. The main effects were qualified by a significant Age x Expression Intensity interaction ($F(4,232) = 26.13$, $p < .001$, $\eta_p^2 = .31$).

To further examine the Age x Expression Intensity interaction for anger, a simple main effects analysis was conducted. First, an independent t-test compared proportion match for younger adults and older adults at each Express Intensity of anger. Younger and older adults were not statistically different in their recognition of emotions at the 20% Expression Intensity level ($t(45.59) = 0.91$, $p = .37$). There were significant age-related differences for emotion recognition at 40% ($t(37.95) = 4.73$, $p < .001$), 60% ($t(37.81) = 8.48$, $p < .001$), 80% ($t(52.96) = 9.21$, $p < .001$), and 100% ($t(58) = 7.73$, $p < .001$) with older adults having significantly lower proportion match for these intensities of anger than younger adults. These data indicate that younger and adults had similar (but low) proportion match for 20% intensity of anger, whereas younger adults had higher proportion match than older adults for higher intensities of anger.

Second, a set of 10 paired t-tests was conducted for each age group comparing all possible pairs of Expression Intensity for anger. Appendix M has details on these paired t-tests. When labeling anger, younger adults' proportion match was significantly lower for lower Expression Intensities (i.e., 20% and 40%) than for higher intensities (i.e., 60%, 80%, and 100%). These analyses are consistent with a visual inspection of the data indicating that younger adults' emotion recognition was lowest for anger at 20% Expression Intensity, followed by 40% (Figure 4). These data suggest that younger adults had lower proportion match for lower Expression Intensities of anger than higher intensities.

Older adults' emotion recognition did not differ significantly among any of the Expression Intensity levels for anger. That is, older adults had similar proportion match (means ranged from .05 to .16) for anger at all Expression Intensities (Figure 4). Note also that their level of proportion match was quite low overall.

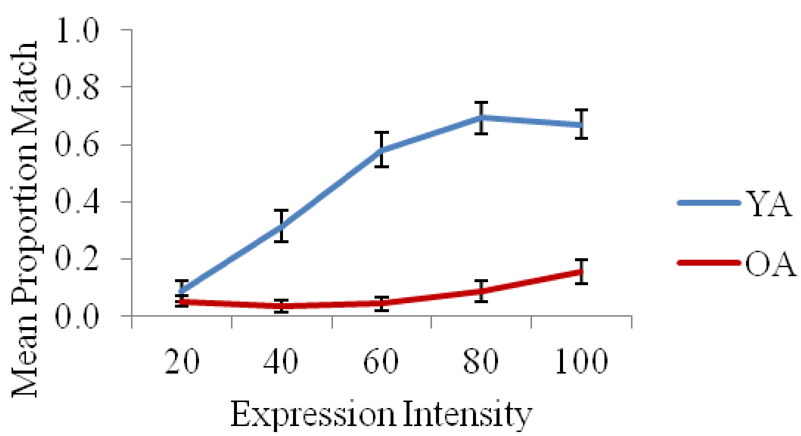

Figure 4. Younger and older adults' proportion match for different intensities of anger. YA = Younger Adults. OA = Older Adults.

Disgust

A main effect of age was found for disgust ($F(1,58) = 17.76$, $p < .001$, $\eta_p^2 = .23$), with older adults having significantly lower proportion match than younger adults. The main effect of Expression Intensity was also statistically significant ($F(3.84,222.97) = 30.26$, $p < .001$, $\eta_p^2 = .34$). Paired t-tests comparing all Expression Intensities of disgust were conducted to further explore this main effect (see Appendix N for details). The analyses revealed that lower intensities of disgust (e.g., 20% and 40%) were more difficult to label than higher intensities (e.g., 60%, 80%, and 100%) for all participants. The interaction of Age and Expression Intensity was not statistically significant ($F(3.84,222.97) = 0.80$, $p = .52$, $\eta_p^2 = .01$). Figure 5 shows the pattern of younger and older adults' emotion recognition at all Expression Intensities of disgust.

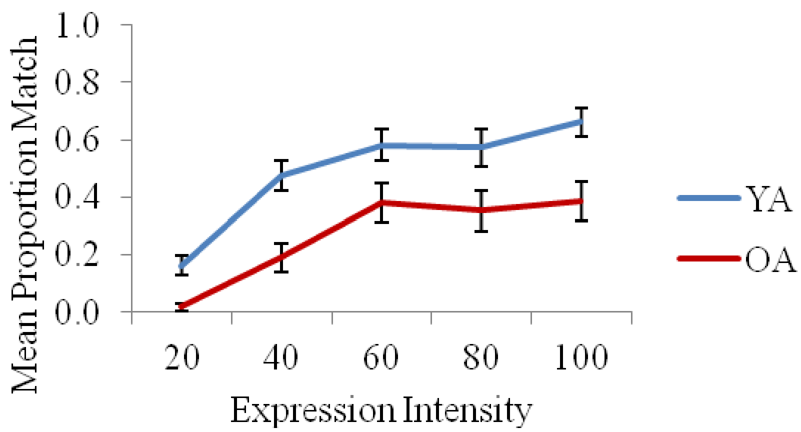

Figure 5. Younger and older adults' proportion match for different intensities of disgust. YA = Younger Adults. OA = Older Adults.

Fear

There was a statistically significant main effect of age for fear ($F(1,58) = 19.54$, $p < .001$, $\eta_p^2 = .25$) with older adults having statistically lower proportion match than younger adults. The main effect of Expression Intensity also reached statistical significance ($F(3.70,214.57) = 29.86$, $p < .001$, $\eta_p^2 = .34$). Appendix O contains details on the paired t-tests that investigated this main effect. The interaction of Age and Expression Intensity was not statistically significant for fear ($F(3.70,214.57) = 1.25$, $p = .29$, $\eta_p^2 = .02$). Figure 6 shows emotion recognition for younger and older adults at all Expression Intensities of fear.

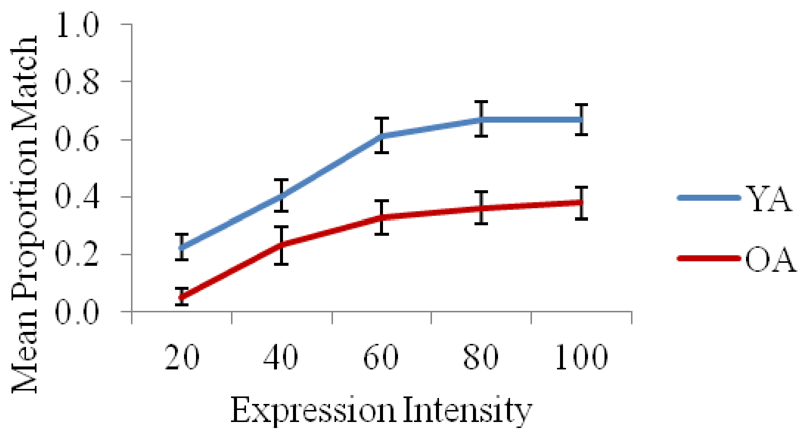

Figure 6. Younger and older adults' proportion match for different intensities of fear. YA = Younger Adults. OA = Older Adults.

Happiness

A significant main effect of age was found for happiness ($F(1,58) = 17.86$, $p < .001$, $\eta_p^2 = .24$), with older adults having statistically lower emotion recognition than younger adults. A significant main effect of Expression Intensity was also found ($F(2.28,132.40) = 24.13$, $p < .001$, $\eta_p^2 = .29$). Appendix P contains details on the paired t-tests conducted to further investigate this main effect. The interaction of Age and Expression Intensity was not statistically significant for happiness ($F(2.28,132.40) = 1.32$, $p = .27$, $\eta_p^2 = .02$). A visual inspection of the data shows that younger adults were at ceiling for proportion match when labeling happiness (Figure 7).

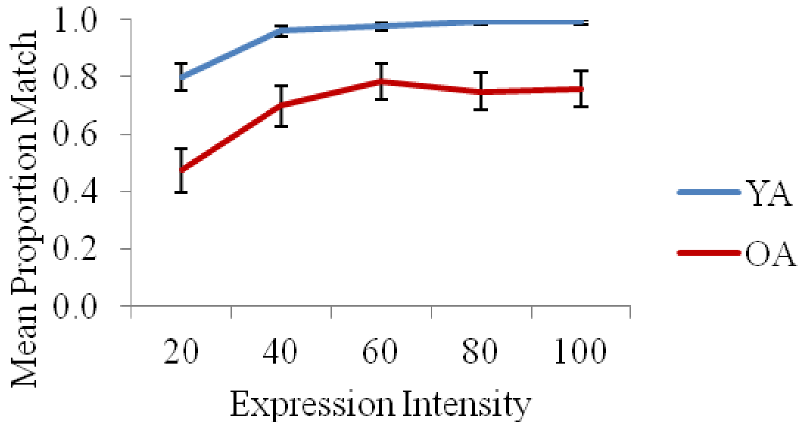

Figure 7. Younger and older adults' proportion match for different intensities of happiness. YA = Younger Adults. OA = Older Adults.

Sadness

A significant main effect of age for sadness was found ($F(1,58) = 35.13$, $p < .001$, $\eta_p^2 = .38$), with younger adults having significantly higher proportion match than older adults. There was also a statistically significant main effect of Expression Intensity ($F(3.68,213.52) = 86.88$, $p < .001$, $\eta_p^2 = .60$). For younger and older adults' emotion recognition at all Expression Intensities of sadness, see Figure 8. The main effects were qualified by a significant Age x Expression Intensity interaction for sadness ($F(3.68,213.52) = 9.12$, $p = .03$, $\eta_p^2 = .05$).

To further examine the Age x Expression Intensity interaction for sadness, a simple main effects analysis was conducted. First, one independent t-test comparing younger and older adults' proportion match was conducted for each Express Intensity. Similar to the pattern seen for anger, younger and older adults did not differ statistically in proportion match at the 20% Expression Intensity level ($t(49.81) = 0.91$, $p = .04$). However, there were age-related differences in proportion match at 40% ($t(58) = 4.11$, $p < .001$), 60% ($t(36.56) = 4.63$, $p < .001$), 80% ($t(38.32) = 3.99$, $p < .001$), and 100% ($t(33.49) = 5.36$, $p < .001$). For sadness, older adults had significantly lower proportion match than younger adults at all Expression Intensities, except 20%.

Second, a set of 10 paired t-tests compared all levels of Express Intensity for sadness. Each set of 10 t-tests was conducted separately for younger and older adults. Appendix Q includes details on these paired t-tests. Younger adults had statistically lower proportion match for lower Expression Intensities (i.e., 20% and 40%) than higher intensities (i.e., 60%, 80%, and 100%). This is consistent with a visual inspection of the data indicating that younger adults' proportion match was lowest for sadness at 20% intensity, followed by 40% (Figure 8). These data suggest that younger adults had worse emotion recognition for lower Expression Intensities than higher ones of sadness. Older adults exhibited the same pattern as younger adults for sadness.

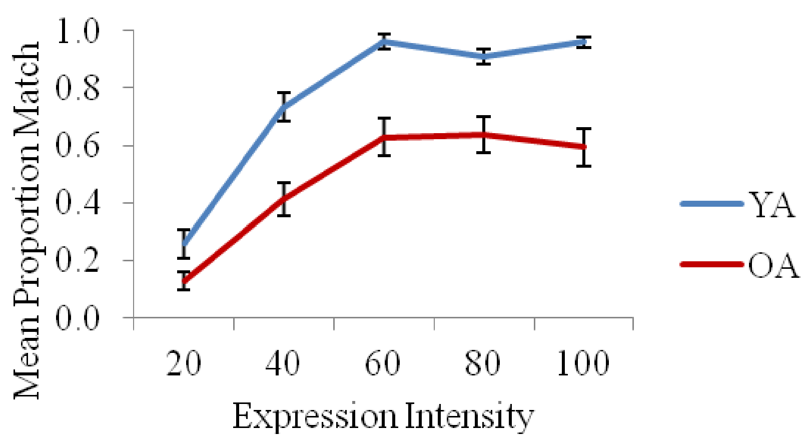

Figure 8. Younger and older adults' proportion match for different intensities of sadness. YA = Younger Adults. OA = Older Adults.

Surprise

The main effect of age did not reach statistical significance ($F(1,58) = 9.12$, $p = .45$, $\eta_p^2 = .14$) which suggests that younger and older adults had similar proportion match for surprise. There was a main effect of Expression Intensity ($F(2.94,170.70) = 9.12$, $p < .001$, $\eta_p^2 = .14$). Appendix R contains details on the paired t-tests conducted to further investigate this main effect. The interaction of Age and Expression Intensity was not statistically significant for surprise ($F(2.94,170.70) = 0.06$, $p = .98$, $\eta_p^2 = .001$). Figure 9 shows younger and older adults' emotion recognition at all Expression Intensities for surprise.

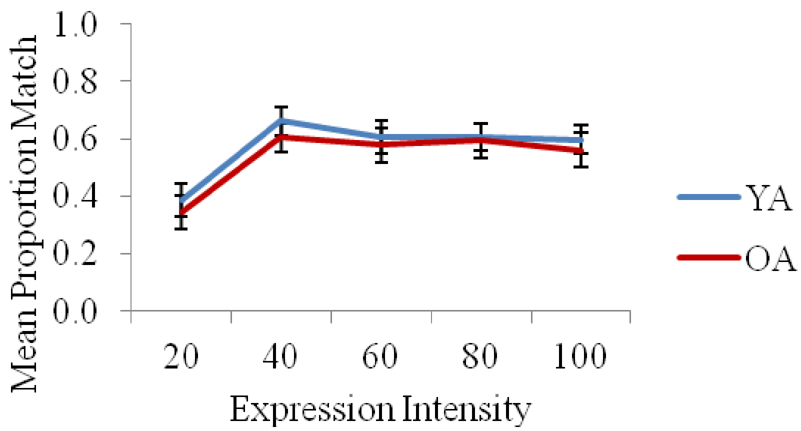

Figure 9. Younger and older adults' proportion match for different intensities of surprise. YA = Younger Adults. OA = Older Adults.

Misattributions of Emotion for Younger and Older Adults at Low and High Expression Intensities

Attribution matrices were created for low Expression Intensity and high Expression Intensity for each age group to assess Emotion Expression misattributions (Tables 6-9). Low Expression Intensity is a combination of 20% and 40% intensities, whereas high Expression Intensity is a combination of 60%, 80%, and 100% intensities. Intensities were grouped for easier interpretation of the data, and because both younger and older adults had statistically lower proportion match for the low intensities than the high intensities.

The rows in the attribution matrices represent the Emotion Expression displayed by the experimental program, and the columns represent the Emotion Expression selected as a response by participants. Each cell represents the proportion of the total number of trials that displayed an Emotion Expression (rows) and what Emotion Expression it was attributed to (columns) across all participants. Grey cells are the proportion match, or the total trials that the participants' selection matched the Emotion Expression designed to display.

Younger Adult Misattributions of Emotion Expression at Low and High Intensities

Younger adults demonstrated more misattributions for low intensity Emotion Expressions than high intensity (Tables 6-7). For low Expression Intensities, Emotion Expressions were most often times misattributed as neutral, or as no emotion. For high Expression Intensities, younger adults commonly misattributed anger with disgust, and fear with surprise. High intensities of happiness and sadness were rarely misattributed (≥ 94% match). This suggests anger, disgust, fear, and surprise were more difficult for younger adults to label than happiness or sadness.

Table 6

Emotion attributions made by younger adults for low intensity emotions

Younger Adult Low Expression Intensity								
		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.20	0.12	0.01	0.04	0.04	0.01	0.58
	Disgust	0.15	0.32	0.03	0.02	0.06	0.04	0.39
	Fear	0.00	0.02	0.31	0.01	0.10	0.36	0.19
	Happy	0.00	0.00	0.00	0.88	0.02	0.02	0.08
	Sad	0.05	0.05	0.03	0.00	0.50	0.01	0.36
	Surprise	0.00	0.02	0.18	0.02	0.07	0.52	0.19

Table 7

Emotion attributions made by younger adults for high intensity emotions

		Younger Adult High Expression Intensity						
		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.65	0.23	0.00	0.00	0.05	0.00	0.07
	Disgust	0.33	0.60	0.01	0.00	0.02	0.02	0.02
	Fear	0.00	0.01	0.65	0.00	0.03	0.30	0.00
	Happy	0.00	0.00	0.00	0.99	0.00	0.01	0.01
	Sad	0.01	0.03	0.01	0.00	0.94	0.01	0.01
	Surprise	0.01	0.01	0.37	0.00	0.01	0.60	0.00

Older Adult Misattributions of Emotion Expression at Low and High Intensities

Older adults demonstrated more misattributions for low intensity Emotion Expressions than high intensity (Tables 8-9). Older adults commonly misattributed a low intensity Emotion Expression as neutral, or no emotion. For high Expression Intensities, older adults misattributed anger the most; it was most frequently misattributed as sadness, neutral, or disgust. Additionally, fear and surprise were often misattributed as one another. High intensity happiness was least misattributed by older adults.

Table 8

Emotion attributions made by older adults for low intensity emotions

		Older Adult Low Expression Intensity						
		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.04	0.04	0.02	0.01	0.13	0.03	0.73
	Disgust	0.05	0.12	0.03	0.05	0.23	0.08	0.45
	Fear	0.07	0.05	0.14	0.03	0.05	0.35	0.31
	Happy	0.00	0.03	0.03	0.58	0.07	0.05	0.23
	Sad	0.04	0.13	0.05	0.01	0.25	0.07	0.45
	Surprise	0.05	0.03	0.14	0.09	0.03	0.42	0.24

Table 9

Emotion attributions made by older adults for high intensity emotions

		Older Adult High Expression Intensity						
		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.11	0.18	0.03	0.01	0.36	0.02	0.30
	Disgust	0.10	0.38	0.05	0.03	0.31	0.06	0.07
	Fear	0.08	0.02	0.33	0.02	0.02	0.50	0.02
	Happy	0.01	0.02	0.02	0.75	0.05	0.10	0.04
	Sad	0.11	0.14	0.04	0.01	0.63	0.04	0.04
	Surprise	0.04	0.01	0.22	0.11	0.01	0.59	0.01

Misattribution of Emotion: Age-related Differences at Low and High Intensities

Overall, younger adults demonstrated fewer misattributions than older adults. Both younger and older adults commonly misattributed low Expression Intensities as neutral. For high Expression Intensities, both age groups made few misattributions of happiness and frequently misattributed fear with surprise. However, they differed in their attributions of anger, disgust, and sadness. Younger adults often misattributed high intensity anger as disgust, whereas older adults were much more distributed in their misattributions.

Emotion Recognition over Time

Age-related differences in proportion match were investigated to determine if emotion recognition changed during the course of the experiment. Proportion match was compared across the four blocks of experimental trials for younger and older adults respectively. Younger adults did show an effect of time ($F(3,90) = 4.65$, $p = .01$, $\eta_p^2 = .13$) whereas older adults did not ($F(3,84) = 0.39$, $p = .76$, $\eta_p^2 = .01$) (Figure 10).

Paired t-tests revealed that younger adults significantly improved emotion recognition between Block 1 and Block 3 ($t(30) = -3.50$, $p = .001$). They did not statistically differ in their proportion match comparing the other blocks. Numerically, the proportion match increased over the first three blocks of trials but decreased from Block 3 to Block 4. This decrease in proportion match may have been due to fatigue or lack of motivation for the younger adults toward the end of the experiment. However, older adults did not experience the same decrease in proportion match. The pattern of emotion attributions did not change over time for younger or older adults (see Appendix S for emotion attributions).

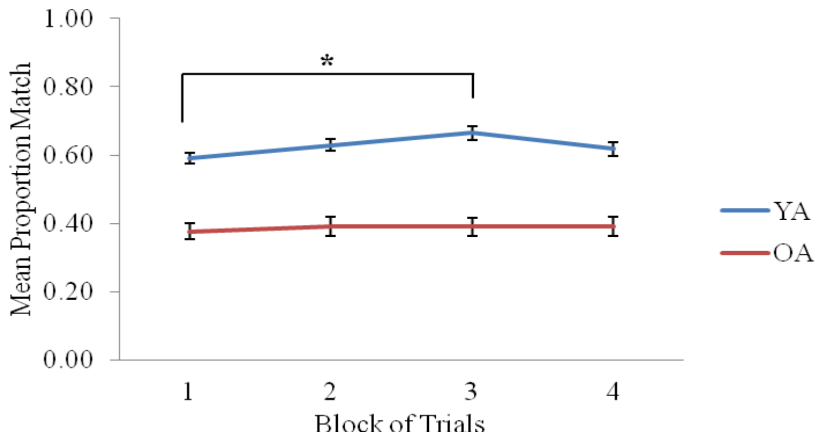

Figure 10. Younger and older adults' proportion match over four blocks of experimental trials. The paired t-tests were Bonferroni corrected. YA = younger adults. OA = older adults.
* $p < .008$.

Summary of Age-related Differences

In general, younger adults demonstrated higher proportion match than older adults for all Emotion Expressions excluding surprise, which did not show age-related differences. Both younger and older adults had lower proportion match for lower Expression Intensities (e.g., 20% and 40%) than higher intensities (e.g., 60%, 80%, and 100%) with the exception of anger. Older adults' proportion match was similar for anger regardless of Expression Intensity. For anger and sadness, older adults had significantly lower proportion match than younger adults at all Expression Intensities except 20%.

For low Expression Intensities, both younger and older adults commonly misattributed low intensity Emotion Expressions as neutral. For high Expression Intensities, both younger and older adults misattributed happiness the least, and misattributed anger the most. Younger adults misattributed anger as disgust, whereas older adults misattributed anger as sadness, neutral, and disgust. Additionally, both age groups commonly misattributed fear as surprise. Patterns of emotion attribution did not change over the time course of the experiment, but proportion match did change for younger adults. Proportion match improved significantly for younger adults from Block 1 of experimental trials to Block 3.

Feature Discrimination

The analyses so far indicate where participants have made misattributions, but not why they occurred. The features of the virtual agent's Emotion Expressions were compared to investigate whether frequent misattributions were a result of similarities between the facial feature configurations. The OPPR software, used to program the Virtual iCat, assigns numbers to the position of each facial feature. This numerical value of feature position was used to calculate difference scores between pairs of Emotion Expressions.

The numerical representation of facial feature position ranged from -100 to 100 for all features, except for eyelids which ranged from 0 to 100. A difference score was calculated between Emotion Expressions for all facial features that were manipulated: eyebrows, eyelids, eye gaze, upper lip, and lower lip. The absolute value of these difference scores were then summed to provide a feature difference score. This was then converted into a proportion by dividing by the greatest difference score among the features. The greatest possible difference among the features of the total face was 900, for the upper face (i.e., eyebrows, eyelids, and eye gaze) was 500, and for the lower face (i.e., upper and lower lips) was 400. The similarity proportion was calculated using these values and the following equation:

Similarity = 1.0 – [(sum of absolute values of feature difference scores) / (greatest possible difference score)]

The maximum value is 1.0 and greater numbers indicate greater similarity. The similarity proportions for each Emotion Expression at 100% Expression Intensity are in Table 10. The most intense Emotion Expressions are presented because the expressions had the greatest difference from one another (similarity ranged from .48 to .93) as opposed to lower Expression Intensities (e.g., 20% intensity similarity ≥ .90). As such, it is easier to compare similarity proportions and to determine patterns. Appendix T contains similarity proportions for all Expression Intensities lower than 100%. These numerical values for feature placements of anger, fear, happiness, sadness, and neutral were obtained with permission from Beer (2010). To determine if similar Emotion Expressions are often misattributed as one another, younger and older adults' attributions of emotion are also included in Table 10.

Feature Discrimination of the Total Face

The results of this study are mixed in terms of supporting the relationship between the similarity proportion of features and emotion attribution. Both younger and older adults' attributions related to the similarity proportion for several emotions. For example, fear and surprise are highly similar (similarity = .93) and were more often attributed with one another than with any other Emotion Expressions. Furthermore, happiness was the most dissimilar from other Emotion Expressions (similarity with other emotions ranged from .48 to .73) and participants' attributions matched this by making the fewest misattributions for happiness. This is consistent with the relationship between similar expressions are misattributed to one another.

However, younger adults generally seem to have a stronger relationship between similarity and attribution than older adults. For example, younger adults most often misattributed disgust with anger, the most similar Emotion Expressions to disgust (similarity = .86). In contrast, older adults most commonly misattributed disgust with sadness, which is one of the least similar Emotion Expressions to disgust (similarity = .66). A similar pattern for younger and older adults can be seen for anger. That is, younger adults most often misattributed anger with disgust (its most similar Emotion Expression at .86) whereas older adults most often misattributed anger with sadness (similarity = .67). Older adults did misattribute anger with disgust and neutral (similarity ranged from .83 to .86) but to a much lesser extent. Similarity of features is not as consistent with older adults' attributions as it is for younger adults' attributions.

Table 10

Similarity proportions and emotion attributions for 100% intensity emotions

Emotion Displayed		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
	Anger							
	Similarity (total)	**1.00**	**0.86**	**0.63**	**0.56**	**0.67**	**0.58**	**0.83**
	Similarity (upper face)	*1.00*	*0.99*	*0.52*	*0.76*	*0.65*	*0.52*	*0.77*
	Similarity (lower face)	*1.00*	*0.70*	*0.76*	*0.30*	*0.70*	*0.65*	*0.90*
	YA Attribution	**0.67**	**0.27**	**0.00**	**0.00**	**0.03**	**0.00**	**0.02**
	OA Attribution	**0.18**	**0.15**	**0.04**	**0.00**	**0.46**	**0.02**	**0.15**
	Disgust							
	Similarity (total)	**0.86**	**1.00**	**0.70**	**0.55**	**0.66**	**0.68**	**0.73**
	Similarity (upper face)	*0.99*	*1.00*	*0.51*	*0.75*	*0.64*	*0.51*	*0.76*
	Similarity (lower face)	*0.70*	*1.00*	*0.94*	*0.30*	*0.70*	*0.90*	*0.70*
	YA Attribution	**0.31**	**0.66**	**0.00**	**0.00**	**0.00**	**0.02**	**0.00**
	OA Attribution	**0.11**	**0.40**	**0.05**	**0.02**	**0.36**	**0.04**	**0.02**
	Fear							
	Similarity (total)	**0.63**	**0.70**	**1.00**	**0.53**	**0.80**	**0.93**	**0.76**
	Similarity (upper face)	*0.52*	*0.51*	*1.00*	*0.76*	*0.83*	*1.00*	*0.75*
	Similarity (lower face)	*0.76*	*0.94*	*1.00*	*0.24*	*0.76*	*0.84*	*0.76*
	YA Attribution	**0.00**	**0.01**	**0.67**	**0.00**	**0.02**	**0.31**	**0.00**
	OA Attribution	**0.09**	**0.02**	**0.37**	**0.01**	**0.02**	**0.48**	**0.01**
	Happy							
	Similarity (total)	**0.56**	**0.55**	**0.53**	**1.00**	**0.48**	**0.60**	**0.73**
	Similarity (upper face)	*0.76*	*0.75*	*0.76*	*1.00*	*0.87*	*0.76*	*0.99*
	Similarity (lower face)	*0.30*	*0.30*	*0.24*	*1.00*	*0.00*	*0.40*	*0.40*
	YA Attribution	**0.00**	**0.00**	**0.00**	**0.99**	**0.00**	**0.01**	**0.00**
	OA Attribution	**0.01**	**0.02**	**0.02**	**0.74**	**0.06**	**0.11**	**0.03**
	Sad							
	Similarity (total)	**0.67**	**0.66**	**0.80**	**0.48**	**1.00**	**0.73**	**0.76**
	Similarity (upper face)	*0.65*	*0.64*	*0.83*	*0.87*	*1.00*	*0.83*	*0.88*
	Similarity (lower face)	*0.70*	*0.70*	*0.76*	*0.00*	*1.00*	*0.60*	*0.60*
	YA Attribution	**0.01**	**0.02**	**0.01**	**0.00**	**0.96**	**0.00**	**0.00**
	OA Attribution	**0.13**	**0.14**	**0.05**	**0.01**	**0.63**	**0.03**	**0.01**
	Surprise							
	Similarity (total)	**0.58**	**0.68**	**0.93**	**0.60**	**0.73**	**1.00**	**0.71**
	Similarity (upper face)	*0.52*	*0.51*	*1.00*	*0.76*	*0.83*	*1.00*	*0.75*
	Similarity (lower face)	*0.65*	*0.90*	*0.84*	*0.40*	*0.60*	*1.00*	*0.65*
	YA Attribution	**0.01**	**0.00**	**0.40**	**0.00**	**0.00**	**0.60**	**0.00**
	OA Attribution	**0.02**	**0.02**	**0.23**	**0.11**	**0.01**	**0.61**	**0.00**

Feature Discrimination of Upper and Lower Regions of the Face

Similarity was calculated for not only the total face, but also on the upper part of the face (eye region) and the lower part of the face (mouth region) separately (Table 10). Previous research has found that older adults may attend to the mouth region of the face more than the eye region (Sullivan et al., 2007). As such, older adults should misattribute Emotion Expressions with high similarity between mouth regions. However, the data were not consistent with this relationship of lower face similarity and attribution. For example, the mouth region for disgust was most similar to fear (similarity = .94) and surprise (similarity = .90). However, older adults infrequently misattributed disgust with fear or surprise. A comparable pattern was seen for older adults' misattributions of anger. The mouth region for anger is most similar to neutral (similarity = .90), but older adults most frequently misattributed anger with sadness (similarity = .70). These data are inconsistent with older adults utilizing the eye region to attribute emotions.

Younger adults' misattributions were not consistent with this relationship of lower face similarity and attribution (Table 10). For example, the mouth region was most similar to anger (similarity = .90) and fear (similarity = .76). Yet, younger adults infrequently misattributed anger as neutral or fear. Younger adults' misattributions may have utilized eye regions with similar feature placement. For instance, anger and disgust have highly similar upper face regions (similarity = .99) and younger adults misattributed anger as disgust most often. However, the most similar upper face regions are also the most similar total face. Thus, it remains unclear if younger adults' attributions are consistent with utilizing the similarity of eye regions or the total face.

Summary of Feature Discrimination

Using numerical representations of feature position provided by the OPPR software, similarity proportions were calculated for each Emotion Expression at 100% intensity and neutral (Table 10). These similarities were compared to younger and older adults' attribution of emotions. The relationship between similarity of features and emotion attribution was not entirely consistent, but patterns suggest that similarity could have played a role in labeling Emotion Expressions. It may have played a larger role for younger adults than older adults. Data were not consistent with older adults attributing emotions based on similarity of upper or lower face regions, whereas younger adults may have considered the upper face region to label emotions. Similarities for Expression Intensities lower than 100% are in Appendix T.

CHAPTER 4

DISCUSSION

This study was designed to assess the effects of age, motion, emotion, and expression intensity on recognizing emotion display by a virtual agent. Previous research with human and synthetic human faces has provided evidence of a dynamic advantage, or increased recognition of emotion when viewing a face in motion versus a static picture (Ambadar et al., 2005; Bould & Morris, 2008; Bould, Morris, & Wink, 2008; Wehrle et al., 2000). The current study extended the investigation of the dynamic advantage found with human faces to that of virtual agents. More specifically, the following questions were addressed: (1) does motion influence emotion recognition of a virtual agent's facial expression?; and (2) are there age-related differences in emotion recognition of a virtual agent's facial expression?

Motion condition did influence emotion recognition of the 80% intensity of disgust as well as the 80% and 100% intensities of surprise for all participants combined, with better emotion recognition in the static condition than in the dynamic condition. Motion condition did not affect emotion recognition for younger adults in either proportion match or pattern of emotion attribution. It did affect older adults' emotion recognition in proportion match, but not in pattern of emotion attribution. Older adults had worse emotion recognition in the dynamic condition than in the static condition. Additionally, both age groups had lower proportion match for low expression intensities than high expression intensities.

Younger adults had higher proportion match and made fewer misattributions of emotion than older adults for anger, fear, disgust, happiness, and sadness. There were no age-related differences in proportion match for surprise, which was often misattributed as fear by both younger and older adults. For low expression intensities (20% and 40%), emotion expression were frequently misattributed as neutral. For high expression intensities (60%, 80%, and 100%), happiness was correctly attributed most frequently, and anger was misattributed most frequently by both younger and older adults. Younger adults were less distributed in their misattributions than older adults. For example, younger adults commonly misattributed anger as disgust, whereas older adults misattributed anger as sadness, neutral, or disgust. Younger adults rarely misattributed sadness (proportion match = .94) whereas older adults frequently misattributed sadness as disgust or anger.

Theoretical Implications

Previous research in emotion recognition focused primarily on the proportion of participants' responses that matched the emotion a face was intended to display. In contrast, this study not only analyzed emotion recognition by proportion match but also by the nature of participants' emotion attributions, or labels. Investigating emotion recognition in this way may provide insights into mechanisms of age-related differences.

One notable exception to focusing the research on proportion match was a study conducted by Beer (2010) that examined the pattern of emotion attributions, or labels, for different static emotions of different characters, including the Virtual iCat. However, only a medium intensity for all characters (60% intensity for the Virtual iCat) was examined for a limited range of expressions (anger, fear, happiness, sadness, and neutral). The current study expanded on Beer's (2010) research with the Virtual iCat by including dynamic and static expressions, five intensities of expression (20%, 40%, 60%, 80%, and 100%), and the expressions of disgust and surprise.

Using patterns of emotion attribution may provide insight into why age-related differences in emotion recognition occur. There are several accounts such as the positivity effect and age-related cognitive decline that attempt to explain why younger and older adults differ in labeling emotions displayed by human and synthetic human faces. However, do these accounts explain the age-related differences in recognizing emotions displayed by virtual agents? Additionally, could these age-related differences in emotion recognition be explained by feature discrimination? That is, people may misattribute expressions with similarly positioned facial features.

Positivity Effect

The positivity effect postulates that older adults remember, attend to, and behave in ways that favor positive information over negative information (Carstensen & Mikels, 2005). For instance, older adults focused on positive facial expressions (e.g., happiness) more than negative ones (e.g., anger and sadness) when pictures were shown in pairs (Mather & Carstensen, 2003). From the positivity effect, one would predict that older adults would show a bias toward labeling expressions as positive. On the whole, the positivity effect cannot explain the age-related differences in emotion recognition found in this study.

Of the six basic emotions shown in the study, happiness is the only unambiguously positive emotion whereas surprise can be considered positive (e.g., a surprise birthday party) or negative (a nasty surprise such as a burst water pipe). Consistent with the positivity effect, older adults demonstrated the highest proportion match for happiness as compared to the other emotions. Moreover, older adults labeled fear as surprise more often than they labeled it as fear. Younger adults also labeled fear as surprise, but not more so than they labeled fear as fear. This suggests that older adults chose to label a negative emotion (e.g., fear) as a relatively more positive emotion (e.g., surprise).

In contradiction to the positivity effect, older adults had lower proportion match than younger adults for happiness and sometimes labeled happiness with more negative emotions (about 15% of attributions at high expression intensity). Even for high expression intensity, older adults misattributed happiness with sadness, disgust, fear, and anger. Also, younger and older adults did not differ in proportion match for labeling surprise, the next most positive emotion expression to happiness.

Furthermore, the positivity effect does not account for older adults labeling negative emotions as other negative emotions. Older adults commonly misattributed high intensity disgust as sadness or anger. Younger adults had higher proportion match for disgust than older adults, which is in contrast with previous studies that found that older adults performed just as well (Ruffman et al., 2008) or better than younger adults for labeling disgust (Calder et al., 2003). However, older adults misattributing negative emotions as other negative emotions may be an artifact of the study design which includes four negative emotion response labels. Thus, there is an increased probability of selecting a negative emotion than a positive emotion if older adults were responding randomly.

Consistent with the positivity bias, older adults may attend to less threatening regions of the face when presented with a negative expression. Eye tracking studies have shown that older adults look more at the mouth region of a negative facial expression than younger adults, who look more at the eye region of the face (Sullivan et al., 2007; Wong et al., 2005). Looking at the mouth region has been found to adversely affect recognition of negative emotions such as anger, fear (Sullivan et al.) and sadness (Calder et al., 2000; Wong et al.). However, the current data suggest this bias was not present. Older adults' labels were not consistent with misattributing facial expressions with similar mouth regions. Eye tracking would have to be done to empirically test this question for virtual agents.

Age-related Cognitive Decline

Age-related cognitive decline holds that perceptual and cognitive abilities, such as perceptual speed, working memory capacity (Phillips & Henry, 2005), and fluid ability, decrease with age (Salthouse, 1992). As a cognitive task becomes more demanding, age-related differences are exacerbated (e.g., McDowd & Craik, 1988; Verhaeghen & Cerella, 2002). According to this account, the emotions that younger adults have difficulty labeling (lowest proportion match) will be the same for older adults. It is not that certain expressions are inherently difficult, but that age-related differences lead to difficulties in identifying emotions that were not previously difficult to identify. The findings from this study do not support the cognitive decline account for age-related differences in emotion recognition.

Relative to other emotion expressions, younger adults had the lowest proportion match for anger (proportion match = .47), followed by disgust (.49), fear (.52), surprise (.57), sadness (.76), and happiness (.94). Older adults had the lowest proportion match for anger (.08), followed by fear (.26), disgust (.28), sadness (.48), surprise (.53), and happiness (.68). In accordance with cognitive decline, both younger and older adults had lowest proportion match for anger and highest proportion match for happiness.

However, cognitive decline predicts younger and older adults will have similar patterns of matching across all emotions; this was not observed in the present study. For example, sadness was one of the easiest (second highest proportion match = .76) emotions for younger adults to label whereas older adults had more difficulty labeling sadness (proportion match = .28) relative to other emotions. These findings are consistent with previous research that also found that sadness was relatively easy for younger adults to label and relatively difficult for older adults to label (Ruffman et al., 2008).

Feature Discrimination

Emotion recognition is influenced by both the configuration of facial features, and the position of individual features (McKelvie, 1995). In this account, differences in emotion recognition would be due to similarity or lack thereof between facial expressions. That is, facial expressions with similarly positioned features will be more difficult to distinguish than expressions that are more different. Similarity proportions were calculated for each emotion expression using numerical representations of feature position provided by the OPPR software.

The feature discrimination account better explained younger adults' attributions of emotion than older adults' attributions. For example, younger adults most often misattributed disgust as anger, the emotion most similar to disgust. However, older adults most frequently misattributed disgust as sadness, which is one of the least similar emotions to disgust. Younger adults often misattributed anger with disgust, which were very similar. Older adults commonly misattributed anger with sadness, which is less similar to anger than disgust or neutral. Both younger and older adults misattributed fear with surprise, which are very similar (similarity = .93). Additionally, happiness was the most dissimilar from the other emotions and had the fewest misattributions for both age groups.

However, the current study was not designed to explicitly test this potential explanation that age-related differences are due to the similarity between features in facial expressions. The goal of this study was to examine the similarity between facial features and age-related differences in labeling emotions. Exploring this avenue of research seems promising for future investigations. Similar to Fisher and Tanner's (1992) study on optimal symbol search, perhaps different models of optimal feature search (e.g., discriminability model, componential model) could be tested with emotion recognition of facial expressions.

No one account fully explains the age-related differences in emotion recognition for the virtual agent in this study. All three accounts (positivity effect, cognitive decline, and feature discrimination) only partially explained the emotion recognition differences between younger and older adults. More research is needed to explicitly test these theories and how they apply to recognizing virtual agent facial expressions.

Motion

Another aim of this study was to explore differences in emotion recognition for dynamic versus static facial expressions. In the dynamic condition, participants saw the dynamic formation of an emotion expression from neutral for three seconds, and the final expression remained for 0.25 seconds. In the static condition, participants saw the static picture of a facial expression for 3.25 seconds. Previous studies in the human emotion recognition literature have found a dynamic advantage for labeling facial expressions (Ambadar et al., 2005; Bould & Morris, 2008; Bould, Morris, & Wink, 2008; Wehrle et al., 2000). However, this study did not support a dynamic advantage for labeling emotions of a virtual agent. Younger adults' emotion recognition did not differ between motion conditions, whereas older adults' proportion match was higher for the static condition than in the dynamic condition.

There are several possible explanations for not finding a dynamic advantage. First, previous research used human and synthetic human faces whereas this study used a virtual agent's face. Beer et al. (2010) found that emotion recognition was highest for human faces, followed by synthetic human then Virtual iCat faces. Thus, the dynamic advantage may not apply in the same way to virtual agent faces as it applies to human or synthetic human faces.

Second, participants may rely more on cues from the final arrangement of the expression than its dynamic formation for virtual agents. Participants in the static condition viewed the final expression for 3.25 seconds whereas participants in the dynamic condition viewed the final expression for 0.25 seconds. The difference in the amount of time available to view the final expression could explain why a dynamic advantage was not found.

Third, previous studies confounded motion and static stimuli by displaying the dynamic formation of facial expressions and then leaving the last frame on the screen until participants responded. This confound allowed participants to use both dynamic *and* static cues to identify an emotion. In contrast, this study had a true motion condition such that only the dynamic formation of an emotion was displayed with the final expression paused for 0.25 seconds. The timing was piloted extensively with younger and older adults, and the final expression was paused so that participants – both young and old – could comprehend the final expression.

Applied Implications

Proportion match as well as common misattributions are useful to individuals who design emotionally expressive agents, virtual and robotic. This study supports previous research that younger and older adults do not label a virtual agent's emotion expression in the same way (Beer et al., 2009; 2010). This suggests that designers should consider age-related differences when designing agents in the following ways.

First, designers may wish to use a negative emotion to be displayed by an agent to communicate that it did not understand. Designers should carefully consider which negative emotion to display to accurately convey the intended message. For example, sadness was frequently misattributed by older adults but not by younger adults. Additionally, anger was frequently misattributed by both age groups. Emotion attributions for younger and older adults as provided by this study may be a useful starting place for what negative emotions are commonly mislabeled.

Second, designers may want to predict and take steps to prevent using facial expressions that will be confused by an agent's user. If the designer is developing an agent to be used by younger adults, facial expressions with high similarity proportions were often misattributed by younger adults. This may be especially useful when implementing facial expressions in other agents and with other emotions. Older adults did not seem to consider similarity of expressions when labeling emotions as much as younger adults did. However, more research is needed to understand the reliability and validity of this relationship.

Lastly, designers may wish to use medium to high intensities of facial expressions. Younger and older adults made more misattributions for low intensity emotions (e.g., 20% and 40%) than medium to high intensity emotions (e.g., 60%, 80%, and 100%). They misattributed low intensity emotions most frequently as being neutral, or no emotion. Thus, if designers want an emotion conveyed, they should use medium to high intensities of facial expressions.

Considerations of Scope

This research has a number of theoretical and applied implications for emotion recognition and agent design. However, as with any one experimental study, there are limits to which these implications can be made.

First, emotion recognition in this study was carefully defined as the *match* between the intended emotion displayed and the participant's selection of an emotion label. There may be many reasons why there are age-related differences found for emotion recognition, but they do not directly translate into older adults not being able to recognize a certain emotion, or that they are worse at recognizing emotion than younger adults. Designers create certain emotions to be displayed by agents' facial expressions. It is important to test these facial expressions with users of various ages – including both younger and older adults – because different age groups may perceive and label these emotive expressions differently. Thus, in this study, emotion recognition was not described using the terms "accuracy" or "errors".

Second, the design of the virtual agent's facial expressions was based on an extensive body of research on emotion recognition for human faces (Ekman & Friesen, 1975; 2003 qualitative descriptions of emotions). However, the human face has features that the Virtual iCat face does not. For example, the Virtual iCat cannot tense its lower eyelid or wrinkle its nose which is important for human expressions of anger and disgust respectively (Ekman & Friesen, 1975; 2003). The iCat does not have skin texture, wrinkles, or muscle tension that could provide added cues for labeling facial expressions. However, these may be limitations of other agents as well; the importance of these features needs to be assessed in more depth.

Third, the display timing of the virtual agent's facial expression was based upon considerable pilot testing with younger and older adults. The dynamic and static expressions were designed to control for length of time that an expression was displayed (i.e., expressions were displayed for 3.25 seconds regardless of motion condition). The study was not designed to control for speed of expression formation for different intensities. In other words, to investigate the formation of differ expression intensities there was a design tradeoff in controlling display time and speed of transition. Further investigation of the impact of speed of expression transition on emotion recognition for virtual agent faces is needed.

Conclusion and Future Directions

This study provided one of the first steps toward understanding the role of motion in age-related differences in emotion recognition for virtual agent faces. This study suggests that age-related differences in emotion recognition for human and synthetic human faces are generalizable to virtual agent faces. Why these age-related differences occur for human, synthetic human, and virtual agent faces is not clear. Future research is needed to examine the reasons why these age-related differences occur. One possible next step is to investigate the role of training and emotion recognition. Can older adults be trained to label emotions the same way as younger adults, or vice versa? Note that most studies of emotion recognition do not provide any feedback so this remains an open question.

Additionally, this study provided evidence that motion does play a role in older adult's emotion recognition. It is important to investigate the role of motion in virtual agent expressions further because it is likely that older adults will increasingly interact with emotionally expressive agents. Questions of display timing, transition speed, and expression to expression transitions have yet to be answered for emotion recognition. Ultimately, the goals in this area are to advance theory as well as provide guidelines for designers to implement in emotionally expressive agents.

APPENDIX A

DEMOGRAPHICS AND HEALTH QUESTIONNAIRE

Please answer the following questions. All of your answers will be treated confidentially. Any published document regarding these answers will not identify individuals with their answers. **If there is a question you do not wish to answer, please just leave it blank and go on to the next question.** Thank you in advance for your help.

Background Information

Gender: Male ❿ 1 **Female** ❿ 2 **Age: _______**

.**1. What is your highest level of education?**
. ❿ 1 No formal education
. ❿ 2 Less than high school graduate
. ❿ 3 High school graduate/GED
. ❿ 4 Vocational training
. ❿ 5 Some college/Associate's degree
. ❿ 6 Bachelor's degree (BA, BS)
. ❿ 7 Master's degree (or other post-graduate training)
. ❿ 8 Doctoral degree (PhD, MD, EdD, DDS, JD, etc.)

.**2. Current marital status (check one)**
. ❿ 1 Single
. ❿ 2 Married
. ❿ 3 Separated
. ❿ 4 Divorced
. ❿ 5 Widowed
. ❿ 6 Other (please specify) _________________

.**3. Do you consider yourself Hispanic or Latino?**
. ❿ 1 Yes
. ❿ 2 No

3 a. If "Yes", would you describe yourself:
. ❿ 1 Cuban
. ❿ 2 Mexican
. ❿ 3 Puerto Rican
. ❿ 4 Other (please specify) _________________

4. How would you describe your primary racial group?

. ❿ 1 No Primary Group
. ❿ 2 White Caucasian
. ❿ 3 Black/African American
. ❿ 4 Asian
. ❿ 5 American Indian/Alaska Native
. ❿ 6 Native Hawaiian/Pacific Islander
. ❿ 7 Multi-racial
. ❿ 8 Other (please specify) ______________________

.**5. In which type of housing do you live?**
. ❿ 1 Residence hall/College dormitory
. ❿ 2 House/Apartment/Condominium
. ❿ 3 Senior housing (independent)
. ❿ 4 Assisted living
. ❿ 5 Nursing home
. ❿ 6 Relative's home
. ❿ 7 Other (please specify) ________________
.**6. Is English your primary language?**
. ❿ 1 Yes
. ❿ 2 No

6 a. If "No", What is your primary language?

____

Health Information

1. **1. In general, would you say your health is:**

➓ ➓ ➓ ➓ ➓

Poor Fair Good Very good Excellent

2. **2. Compared to other people your own age, would you say your health is:**

➓ ➓ ➓ ➓ ➓

Poor Fair Good Very good Excellent

3. How satisfied are you with your present health?

➓ ➓ ➓ ➓ ➓

Not at all satisfied | Not very satisfied | Neither satisfied nor dissatisfied | Somewhat satisfied | Extremely satisfied

4. For each of the following conditions please indicate if you have ever had that condition in your life, have the condition now at this time or never had the condition. Check one box for each condition.

Condition	In your lifetime[1]	Now[2]	Never[3]
a. Arthritis			
b. Asthma or Bronchitis			
c. Cancer (other than skin cancer)			
d. Diabetes			
e. Epilepsy			
f. Heart Disease			
g. Hearing Impairment			
h. Hypertension			
i. Stroke			
j. Cataracts			
k. Other Vision Impairment			
l. Other significant illnesses (please list)			

5. Do you wear glasses or contacts?

1Yes 2 No

5a. If you answered Yes to question 5, check all that apply below.

11 glasses 2 bifocals 3 trifocals 4 contact lenses 5 reading 6 other __________

6. Do you have any hearing problems that have not been corrected?

1Yes 2 No

1**6a. If you answered Yes to question 6, check one**.

1 Mild 2 Moderate 3 Severe

Medication Usage Details

Please list all medical products that you are currently taking. Include medicinal herbs, vitamins, aspirin, antacid, nasal spray, laxatives, etc., as well as prescription medications (copy names from label if possible). This information will be completely confidential.

EXAMPLE

Name of Medication: Zarontin

Reason for taking:____epilepsy___

Dosage (ea. time taken): 500 mg How

often do you take the medication? (circle

one) weekly as needed

daily every other day weekly as needed

On days that you take the medication, how many times per day do you take it? _____

3 What time of day do you take the medication? morning, afternoon, evening How long you have been taking the medication? 5 years Does this medication cause any problems? makes me sleepy

.**1.** Name of Medication:
____ Reason for taking:_____________________ Dosage (ea. time taken):________ How often do you take the medication? (circle one) daily every other day weekly as needed On days that you take the medication, how many times per day do you take it? What time of day do you take the medication?
.How long you have been taking medication?
___________________________ Does this medication cause any problems?

.**2.** Name of Medication:
____ Reason for taking:_____________________ Dosage (ea. time taken):________ How often do you take the medication? (circle one) daily every other day weekly as needed On days that you take the medication, how many times per day do you take it? What time of day do you take the medication?
.How long you have been taking medication?
___________________________ Does this medication cause any problems?

.**3.** Name of Medication: ____ Reason for taking:______________________ Dosage (ea. time taken):________ How often do you take the medication? (circle one) daily every other day weekly as needed On days that you take the medication, how many times per day do you take it? What time of day do you take the medication? .How long you have been taking medication? ____________________________ Does this medication cause any problems?

.**4.** Name of Medication: ____ Reason for taking:______________________ Dosage (ea. time taken):________ How often do you take the medication? (circle one) daily every other day weekly as needed On days that you take the medication, how many times per day do you take it? What time of day do you take the medication? .How long you have been taking medication? ____________________________ Does this medication cause any problems?

.**5.** Name of Medication: ____ Reason for taking:______________________ Dosage (ea. time taken):________ How often do you take the medication? (circle one) daily every other day weekly as needed On days that you take the medication, how many times per day do you take it? What time of day do you take the medication? .How long you have been taking medication? ____________________________ Does this medication cause any problems?

.**6.** Name of Medication: ____ Reason for taking:______________________ Dosage (ea. time taken):________ How often do you take the medication? (circle one) daily every other day weekly as needed On days that you take the medication, how many times per day do you take it? What time of day do you take the medication? .How long you have been taking medication? ____________________________ Does this medication cause any problems?

.**7.** Name of Medication: ____ Reason for taking:______________________ Dosage (ea. time taken):________ How often do you take the medication? (circle one) daily every other day weekly as needed On days that you take the medication, how many times per day do you take it? What time of day do you take the medication?

.How long you have been taking medication?
___________________________ Does this medication cause any problems?

.**8.** Name of Medication:
____ Reason for taking:_____________________ Dosage (ea. time taken):________ How often do you take the medication? (circle one) daily every other day weekly as needed On days that you take the medication, how many times per day do you take it? What time of day do you take the medication?
.How long you have been taking medication?
___________________________ Does this medication cause any problems?

2. **9.** Name of Medication:
____ Reason for taking:_____________________ Dosage (ea. time taken):________ How often do you take the medication? (circle one) daily every other day weekly as needed On days that you take the medication, how many times per day do you take it? What time of day do you take the medication?

How long you have been taking medication? ___________________________ Does this medication cause any problems?

APPENDIX B

AGENTS AND EMOTION QUESTIONNAIRE

We would like know about your previous experiences with agents as well as what you thought about today's study. Please remember that there are no right or wrong answers.

1. **Do you have previous experience with robots?**

   YES NO

   If you answered YES, then please describe your experience below.

   ____

   ____

   ____

   ____

   ____

2. **Do you have previous experience with virtual agents (e.g., characters, animations)?**

   YES NO

   If you answered YES, then please describe your experience below.

   ____

   ____

   ____

   ____

   ____

3. **For each technology listed below, please indicate how much experience you have had with the device.** *Check <u>ONE</u> box for each type of technology.*

	Never used$_1$	Used once$_2$	Used on occasion$_3$	Used frequently$_4$	I'm not sure$_0$
Personal robot (e.g., robotic vacuum cleaner)					
Manufacturing robot (e.g., robotic arm in factory)					
Animation (e.g., office assistant in Microsoft Word)					
Robot toy (e.g., Furbie, Sony Aibo)					

4. **Rate how confident you were in identifying the different emotions displayed by the Virtual iCat.** *Check ONE box per emotion.*

	Not confident				Very confident
Anger$_1$	1	2	3	4	5
Disgust$_2$	1	2	3	4	5
Fear$_3$	1	2	3	4	5
Happiness$_4$	1	2	3	4	5
Sadness$_5$	1	2	3	4	5
Surprise$_6$	1	2	3	4	5
Neutral$_7$	1	2	3	4	5

5. **Rate the importance of each facial feature for identifying the following emotion.** *Check ONE box per feature for all emotions.*

ANGER$_1$

	Not important				Very important	Not sure
Eyebrows$_1$	1	2	3	4	5	0
Eye gaze$_2$	1	2	3	4	5	0
Eye lids$_3$	1	2	3	4	5	0
Mouth$_4$	1	2	3	4	5	0

DISGUST$_2$

	Not Important				Very Important	Not Sure
Eyebrows$_1$	1	2	3	4	5	0
Eye gaze$_2$	1	2	3	4	5	0
Eye lids$_3$	1	2	3	4	5	0
Mouth$_4$	1	2	3	4	5	0

FEAR$_3$

	Not Important				Very Important	Not Sure
Eyebrows$_1$	1	2	3	4	5	0
Eye gaze$_2$	1	2	3	4	5	0
Eye lids$_3$	1	2	3	4	5	0
Mouth$_4$	1	2	3	4	5	0

HAPPINESS$_4$

	Not Important				Very Important	Not Sure
Eyebrows$_1$	1	2	3	4	5	0
Eye gaze$_2$	1	2	3	4	5	0
Eye lids$_3$	1	2	3	4	5	0
Mouth$_4$	1	2	3	4	5	0

SADNESS$_5$

	Not Important				Very Important	Not Sure
Eyebrows$_1$	1	2	3	4	5	0
Eye gaze$_2$	1	2	3	4	5	0
Eye lids$_3$	1	2	3	4	5	0
Mouth$_4$	1	2	3	4	5	0

SURPRISE$_6$

	Not Important				Very Important	Not Sure
Eyebrows$_1$	1	2	3	4	5	0
Eye gaze$_2$	1	2	3	4	5	0
Eye lids$_3$	1	2	3	4	5	0
Mouth$_4$	1	2	3	4	5	0

NEUTRAL$_7$

	Not Important				Very Important	Not Sure
Eyebrows$_1$	1	2	3	4	5	0
Eye gaze$_2$	1	2	3	4	5	0
Eye lids$_3$	1	2	3	4	5	0
Mouth$_4$	1	2	3	4	5	0

6. **How did you identify the emotions?** *Circle one.*
    a. I <u>always</u> looked at certain facial features to identify the emotion
    b. I <u>always</u> looked at the face as a whole to identify the emotion
    c. I looked at certain facial features and <u>THEN</u> looked at the face as a whole
    d. I looked at the face as a whole and <u>THEN</u> looked at certain facial features

Thank you for participating in this study!

APPENDIX C

RESPONSE TIME ANOVA SUMMARY TABLE

Table 11

Age x Motion Condition x Emotion Expression x Expression Intensity mixed-measures ANOVA summary table for response time

	df_{num}	df_{den}	F	p	η_p^2
Main effects					
Age (A)	1	56	10.85	.002*	0.16
Motion Condition (M)	1	56	7.77	.007*	0.12
Emotion Expression (E)	5	280	14.15	< .001*	0.20
Expression Intensity (I)	3.83	214.31	9.48	< .001*	0.15
2-way interactions					
A x M	1	56	0.33	.567	0.01
A x E	5	280	4.30	.001*	0.07
A x I	3.83	214.31	5.61	< .001*	0.09
M x E	5	280	1.94	.088	0.03
M x I	3.83	214.31	0.68	.599	0.01
E x I	16.27	911.04	2.30	.002*	0.04
3-way interactions					
A x M x E	5	280	4.22	.001*	0.07
A x M x I	3.83	214.31	0.57	.675	0.01
A x E x I	16.27	911.04	1.11	.336	0.02
M x E x I	16.27	911.04	0.83	.659	0.01
4-way interaction					
A x M x E x I	16.27	911.04	1.03	.420	0.02

Note. The dependent variable is response time (milliseconds). * $p < .05$.

APPENDIX D

RESPONSE TIME GRAPHS

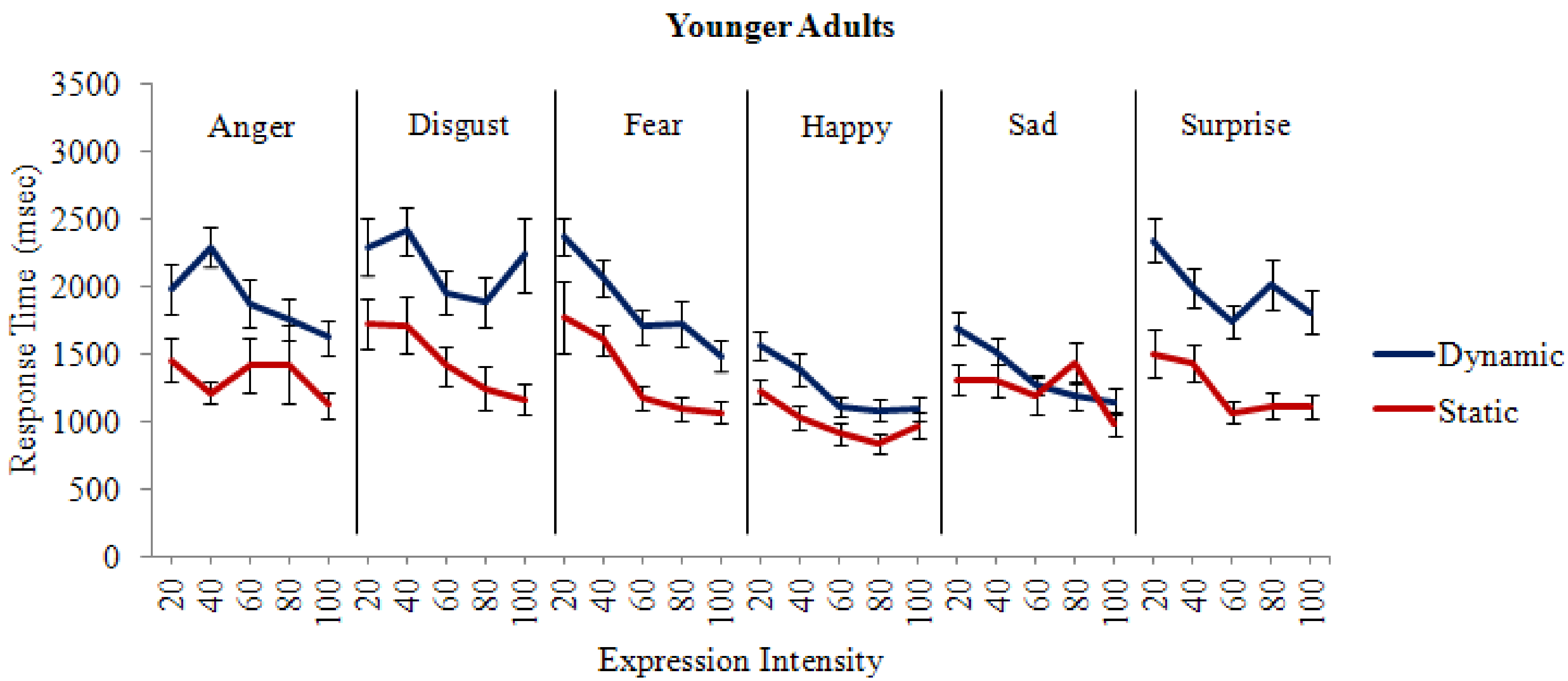

Figure 11. Younger adults' mean response time (msec) for each combination of Expression Intensity and Emotion Expression for the dynamic and static conditions.

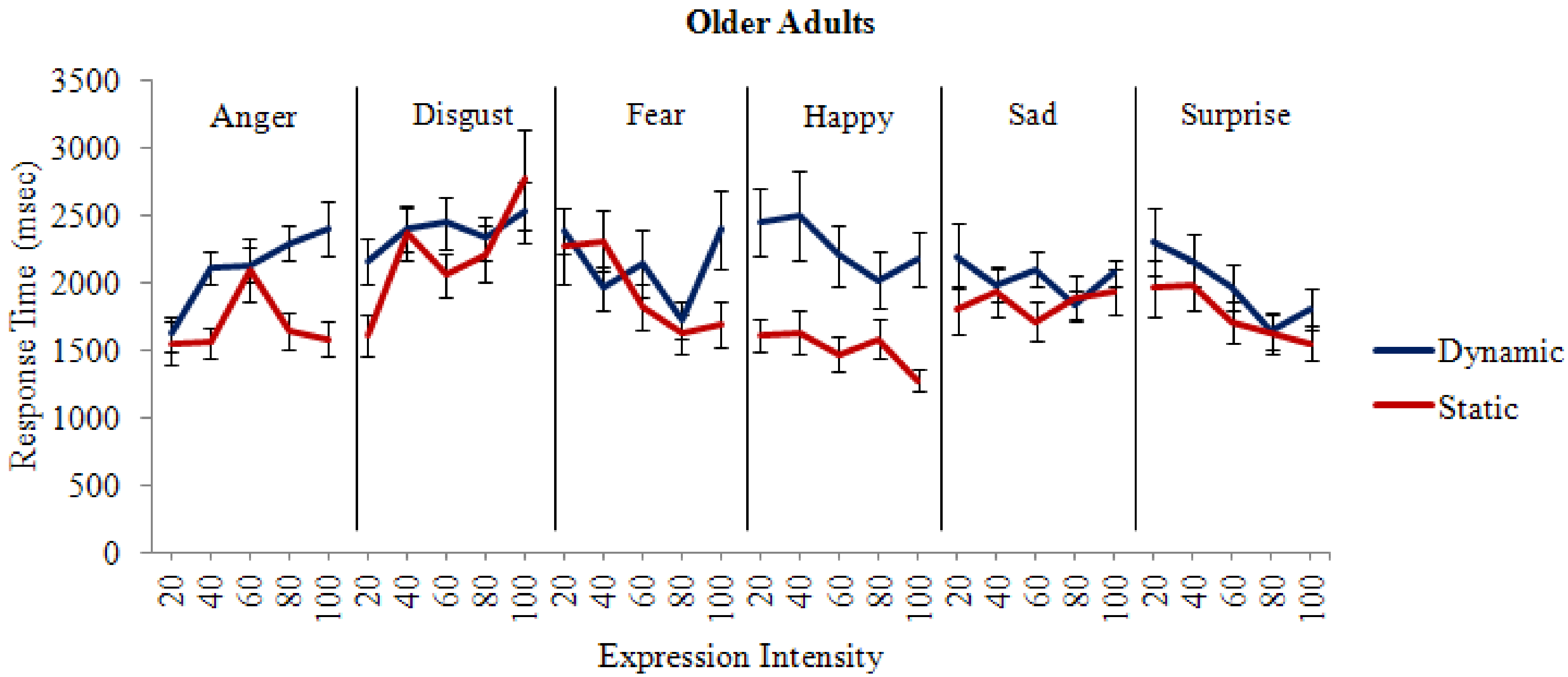

Figure 12. Older adults' mean response time (msec) for each combination of Expression Intensity and Emotion Expression for the dynamic and static conditions.

APPENDIX E

4-WAY ANOVA SUMMARY TABLE

Table 12

Age x Motion Condition x Emotion Expression x Expression Intensity mixed-measures ANOVA summary table for proportion match

		F	df_{num}	df_{den}	p	η_p^2
Main effects						
	Age (A)	80.89	1	56	< .001*	0.59
	Motion Condition (M)	5.20	1	56	< .001*	0.09
	Emotion Expression (E)	72.30	4.81	269.47	< .001*	0.56
	Expression Intensity (I)	179.56	3.35	187.74	< .001*	0.76
2-way interactions						
	A x M	2.58	1	56	0.11	0.04
	A x E	6.22	4.81	269.47	< .001*	0.10
	A x I	6.12	3.35	187.74	< .001*	0.10
	M x E	2.71	4.81	269.47	0.02*	0.05
	M x I	4.65	3.35	187.74	0.00*	0.08
	E x I	6.43	17.26	966.59	< .001*	0.10
3-way interactions						
	A x M x E	0.88	4.81	269.47	0.49*	0.02
	A x M x I	3.19	3.35	187.74	0.02*	0.05
	A x E x I	3.51	17.26	966.59	< .001*	0.06
	M x E x I	4.10	17.26	966.59	< .001*	0.07
4-way interaction						
	A x M x E x I	0.72	17.26	966.59	0.78	0.01

Note. The dependent variable is proportion match. * $p < .05$.

APPENDIX F

MAIN EFFECTS OF MOTION CONDITION ON EMOTION RECOGNITION

Table 13

Motion Condition main effects for all Emotion Expressions

Emotion Expression	Dynamic Condition		Static Condition						
	M	*SD*	*M*	*SD*	*F*	dfnum	dfden	*p*	η_p^2
Anger	.29	.35	.27	.27	.07	1	58	.79	< .01
Disgust	.32	.31	.45	.30	5.12	1	58	.03*	.08
Fear	.42	.30	.37	.33	.66	1	58	.42	.01
Happy	.76	.34	.88	.23	3.31	1	58	.07	.05
Sad	.58	.32	.68	.27	2.49	1	58	.12	.04
Surprise	.52	.29	.59	.28	3.04	1	58	.09	.05

Note. * $p < .05$.

APPENDIX G

EFFECTS OF MOTION AND INTENSITY ON RECOGNIZING DISGUST

Table 14

Proportion match for disgust at all levels of Expression Intensity

Intensity of Disgust	Dynamic Condition					Static Condition				
	M	*SD*	*t*	df	*p*	*M*	*SD*	*t*	df	*p*
20	.09	.15	-4.68	30	< .001*	.09	.17	-5.23	28	< .001*
40	.31	.34				.36	.30			
20	.09	.15	-5.67	30	< .001*	.09	.17	-7.36	28	< .001*
60	.40	.31				.58	.37			
20	.09	.15	-3.66	30	.001*	.09	.17	-8.03	28	< .001*
80	.33	.37				.61	.34			
20	.09	.15	-6.17	30	< .001*	.09	.17	-7.68	28	< .001*
100	.46	.35				.60	.33			
40	.31	.34	-1.19	30	.24	.36	.30	-3.13	28	.004*
60	.40	.31				.58	.37			
40	.31	.34	-.24	30	.81	.36	.30	-3.88	28	.001*
80	.33	.37				.61	.34			
40	.31	.34	-2.26	30	.03	.36	.30	-3.36	28	.002*
100	.46	.35				.60	.33			
60	.40	.31	1.16	30	.25	.58	.37	-.52	28	.61
80	.33	.37				.61	.34			
60	.40	.31	-1.44	30	.16	.58	.37	-.32	28	.75
100	.46	.35				.60	.33			
80	.33	.37	-2.07	30	.05	.61	.34	.14	28	.89
100	.46	.35				.60	.33			

Note: As part of the simple main effects analysis, Bonferroni corrected paired t-tests to explore the statistically significant interaction of Expression Intensity and Motion Condition for disgust. * $p < .0025$.

APPENDIX H

EFFECTS OF MOTION AND INTENSITY ON RECOGNIZING SURPRISE

Table 15

Proportion match for surprise at all levels of Expression Intensity

Intensity of Surprise	Dynamic Condition					Static Condition				
	M	*SD*	*t*	df	*p*	*M*	*SD*	*t*	df	*p*
20	.50	.30	-2.80	30	.01	.22	.26	-6.02	28	< .001*
40	.64	.28				.63	.26			
20	.50	.30	-.11	30	.92	.22	.26	-6.72	28	< .001*
60	.51	.32				.68	.32			
20	.50	.30	.39	30	.70	.22	.26	-6.79	28	< .001*
80	.48	.25				.73	.27			
20	.50	.30	.48	30	.63	.22	.26	-6.32	28	< .001*
100	.46	.28				.71	.26			
40	.64	.28	1.76	30	.09	.63	.26	-1.03	28	.31
60	.51	.32				.68	.32			
40	.64	.28	2.81	30	.01	.63	.26	-1.89	28	.07
80	.48	.25				.73	.27			
40	.64	.28	2.41	30	.02	.63	.26	-1.27	28	.21
100	.46	.28				.71	.26			
60	.51	.32	.55	30	.59	.68	.32	-.90	28	.37
80	.48	.25				.73	.27			
60	.51	.32	.84	30	.41	.68	.32	-.38	28	.70
100	.46	.28				.71	.26			
80	.48	.25	.30	30	.76	.73	.27	.59	28	.56
100	.46	.28				.71	.26			

Note: As part of the simple main effects analysis, Bonferroni corrected paired t-tests to explore the statistically significant interaction of Expression Intensity and Motion Condition for surprise. * $p < .0025$.

APPENDIX I

INTENSITY EFFECTS ON YOUNGER ADULTS' EMOTION RECOGNITION

Table 16

Younger adults' proportion match at all levels of Expression Intensity

Intensity	*M*	*SD*	*t*	df	*p*
20	.32	.10	-15.16	30	< .001*
40	.59	.11			
20	.32	.10	-21.33	30	< .001*
60	.72	.11			
20	.32	.10	-15.82	30	< .001*
80	.74	.12			
20	.32	.10	-20.46	30	< .001*
100	.76	.08			
40	.59	.11	-6.85	30	< .001*
60	.72	.11			
40	.59	.11	-6.05	30	< .001*
80	.74	.12			
40	.59	.11	-9.30	30	< .001*
100	.76	.08			
60	.72	.11	-1.00	30	.325
80	.74	.12			
60	.72	.11	-2.16	30	.039
100	.76	.08			
80	.74	.12	-1.04	30	.307
100	.76	.08			

Note. Bonferroni corrected paired t-tests to investigate the statistically significant main effect of Expression Intensity for younger adults. * $p < .005$

APPENDIX J

MOTION AND INTENSITY EFFECTS ON OLDER ADULTS' EMOTION RECOGNITION

Table 17

Older adults' proportion match at all levels of Expression Intensity

Intensity	*M*	*SD*	*t*	df	*p*
20	.18	.09	-6.73	28	< .001*
40	.36	.15			
20	.18	.09	-9.28	28	< .001*
60	.46	.16			
20	.18	.09	-7.59	28	< .001*
80	.46	.20			
20	.18	.09	-7.78	28	< .001*
100	.47	.20			
40	.36	.15	-4.12	28	< .001*
60	.46	.16			
40	.36	.15	-4.24	28	< .001*
80	.46	.20			
40	.36	.15	-4.05	28	< .001*
100	.47	.20			
60	.46	.16	-.33	28	.743
80	.46	.20			
60	.46	.16	-.67	28	.507
100	.47	.20			
80	.46	.20	-.47	28	.643
100	.47	.20			

Note. Bonferroni corrected paired t-tests to investigate the statistically significant main effect of Expression Intensity for older adults. * $p < .005$

Table 18

Older adult's proportion match for each Expression Intensity for the dynamic and static conditions

Expression Intensity	Dynamic Condition					Static Condition				
	M	*SD*	*t*	df	*p*	*M*	*SD*	*t*	df	*p*
20	.25	.12	-9.24	30	< .001	.25	.12	-9.86	28	< .001*
40	.47	.18				.47	.18			
20	.25	.12	-9.58	30	< .001	.25	.12	-21.62	28	< .001*
60	.56	.22				.56	.22			
20	.25	.12	-8.45	30	< .001	.25	.12	-14.21	28	< .001*
80	.55	.22				.55	.22			
20	.25	.12	-9.39	30	< .001	.25	.12	-14.46	28	< .001*
100	.58	.22				.58	.22			
40	.47	.18	-4.33	30	< .001	.47	.18	-6.64	28	< .001*
60	.56	.22				.56	.22			
40	.47	.18	-3.19	30	0.003	.47	.18	-8.62	28	< .001*
80	.55	.22				.55	.22			
40	.47	.18	-4.98	30	< .001	.47	.18	-7.32	28	< .001*
100	.58	.22				.58	.22			
60	.56	.22	0.39	30	0.698	.56	.22	-1.77	28	.087
80	.55	.22				.55	.22			
60	.56	.22	-1.48	30	0.150	.56	.22	-1.22	28	.233
100	.58	.22				.58	.22			
80	.55	.22	-2.44	30	0.021	.55	.22	.51	28	.615
100	.58	.22				.58	.22			

Note. Bonferroni corrected paired t-tests as part of the simple main effects analysis investigating the statistically significant interaction of Motion Condition and Expression Intensity for older adults. * $p < .0025$

APPENDIX K

YOUNGER ADULT ATTRIBUTION MATRICES:

EFFECTS OF INTENSITY AND MOTION CONDITION

Table 19

Younger adults' emotion attributions in the dynamic condition for low and high Expression Intensities

Dynamic, Low Expression Intensity

		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.25	0.15	0.01	0.02	0.05	0.02	0.51
	Disgust	0.20	0.31	0.02	0.02	0.03	0.05	0.37
	Fear	0.00	0.02	0.23	0.01	0.06	0.51	0.16
	Happy	0.00	0.00	0.00	0.84	0.02	0.02	0.12
	Sad	0.03	0.07	0.00	0.00	0.45	0.02	0.43
	Surprise	0.01	0.01	0.15	0.02	0.03	0.60	0.18

Dynamic, High Expression Intensity

		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.66	0.23	0.00	0.00	0.05	0.00	0.05
	Disgust	0.41	0.53	0.01	0.00	0.02	0.03	0.01
	Fear	0.01	0.01	0.72	0.00	0.02	0.24	0.00
	Happy	0.00	0.00	0.00	0.98	0.00	0.01	0.01
	Sad	0.00	0.03	0.00	0.00	0.96	0.01	0.01
	Surprise	0.02	0.01	0.44	0.01	0.01	0.52	0.00

Table 20

Younger adults' emotion attributions in the static condition for low and high Expression Intensities

Static, Low Expression Intensity								
		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.15	0.09	0.02	0.06	0.03	0.00	0.65
	Disgust	0.09	0.33	0.03	0.03	0.08	0.03	0.42
	Fear	0.01	0.03	0.40	0.01	0.15	0.20	0.21
	Happy	0.00	0.00	0.01	0.92	0.02	0.01	0.05
	Sad	0.07	0.03	0.07	0.00	0.54	0.01	0.28
	Surprise	0.00	0.03	0.22	0.01	0.11	0.44	0.19
Static, High Expression Intensity								
		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.63	0.23	0.00	0.00	0.04	0.00	0.09
	Disgust	0.24	0.68	0.00	0.01	0.03	0.01	0.03
	Fear	0.00	0.02	0.58	0.00	0.04	0.37	0.00
	Happy	0.00	0.00	0.00	0.99	0.00	0.01	0.01
	Sad	0.01	0.03	0.02	0.00	0.93	0.01	0.00
	Surprise	0.00	0.01	0.29	0.00	0.01	0.69	0.00

APPENDIX L

OLDER ADULT ATTRIBUTION MATRICES:

EFFECTS OF INTENSITY AND MOTION CONDITION

Table 21

Older adults' emotion attributions in the dynamic condition for low and high Expression Intensities

		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Dynamic, Low Expression Intensity								
		Emotion Selected						
Emotion Displayed	Anger	0.05	0.03	0.02	0.01	0.12	0.01	0.76
	Disgust	0.03	0.12	0.03	0.05	0.27	0.08	0.41
	Fear	0.08	0.02	0.18	0.05	0.02	0.41	0.24
	Happy	0.01	0.05	0.03	0.55	0.09	0.02	0.25
	Sad	0.03	0.13	0.02	0.00	0.21	0.04	0.58
	Surprise	0.09	0.03	0.16	0.10	0.02	0.46	0.13
Dynamic, High Expression Intensity								
		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.12	0.15	0.04	0.00	0.42	0.01	0.27
	Disgust	0.10	0.31	0.05	0.05	0.33	0.08	0.07
	Fear	0.11	0.02	0.39	0.01	0.02	0.45	0.01
	Happy	0.01	0.02	0.02	0.72	0.06	0.13	0.05
	Sad	0.12	0.19	0.04	0.01	0.53	0.03	0.07
	Surprise	0.08	0.02	0.30	0.14	0.01	0.46	0.00

Table 22

Older adults' emotion attributions in the static condition for low and high Expression Intensities

Static, Low Expression Intensity

		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.03	0.05	0.01	0.01	0.13	0.05	0.71
	Disgust	0.07	0.13	0.02	0.04	0.18	0.08	0.49
	Fear	0.06	0.07	0.10	0.01	0.07	0.29	0.38
	Happy	0.00	0.02	0.02	0.61	0.06	0.07	0.21
	Sad	0.05	0.13	0.07	0.02	0.29	0.10	0.33
	Surprise	0.01	0.03	0.11	0.07	0.04	0.39	0.35

Static, High Expression Intensity

		Emotion Selected						
		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Emotion Displayed	Anger	0.10	0.21	0.02	0.01	0.31	0.02	0.33
	Disgust	0.10	0.46	0.05	0.01	0.28	0.04	0.06
	Fear	0.04	0.03	0.28	0.03	0.03	0.55	0.03
	Happy	0.00	0.02	0.03	0.78	0.04	0.08	0.03
	Sad	0.09	0.10	0.03	0.00	0.72	0.05	0.00
	Surprise	0.01	0.01	0.15	0.08	0.01	0.72	0.02

APPENDIX M

EFFECTS OF AGE AND EXPRESSION INTENSITY ON RECOGNIZING ANGER

Table 23

Proportion match for anger at all levels of Expression Intensity for younger and older adults

Intensity of Anger	Younger Adults					Older Adults				
	M	*SD*	*t*	df	*p*	*M*	*SD*	*t*	df	*p*
20	.09	.20	-5.14	30	< .001*	.05	.10	.70	28	.49
40	.31	.31				.03	.11			
20	.09	.20	-8.76	30	< .001*	.05	.10	.44	28	.66
60	.58	.33				.04	.12			
20	.09	.20	-10.93	30	< .001*	.05	.10	-.89	28	.38
80	.69	.30				.09	.20			
20	.09	.20	-10.83	30	< .001*	.05	.10	-2.27	28	.03
100	.67	.28				.16	.24			
40	.31	.31	-4.42	30	< .001*	.03	.11	-.57	28	.57
60	.58	.33				.04	.12			
40	.31	.31	-6.99	30	< .001*	.03	.11	-1.80	28	.08
80	.69	.30				.09	.20			
40	.31	.31	-6.56	30	< .001*	.03	.11	-3.31	28	.003
100	.67	.28				.16	.24			
60	.58	.33	-2.19	30	.04	.04	.12	-1.31	28	.20
80	.69	.30				.09	.20			
60	.58	.33	-1.65	30	.11	.04	.12	-2.65	28	.01
100	.67	.28				.16	.24			
80	.69	.30	.44	30	.66	.09	.20	-1.49	28	.15
100	.67	.28				.16	.24			

Note: Bonferroni correct paired t-tests. * $p < .0025$.

APPENDIX N

EFFECT OF EXPRESSION INTENSITY ON RECOGNIZING DISGUST

Table 24

Proportion match for each Expression Intensity of disgust

Intensity of Disgust	*M*	*SD*	*t*	df	*p*
20	.09	.16	-7.04	59	< .001*
40	.34	.32			
20	.09	.16	-9.02	59	< .001*
60	.48	.35			
20	.09	.16	-7.62	59	< .001*
80	.47	.38			
20	.09	.16	-9.70	59	< .001*
100	.53	.35			
40	.34	.32	-2.99	59	.004*
60	.48	.35			
40	.34	.32	-2.67	59	.010
80	.47	.38			
40	.34	.32	-3.99	59	< .001*
100	.53	.35			
60	.48	.35	.39	59	.701
80	.47	.38			
60	.48	.35	-1.02	59	.313
100	.53	.35			
80	.47	.38	-1.40	59	.167
100	.53	.35			

Note. Bonferroni corrected paired t-tests. * $p < .005$.

APPENDIX O

EFFECT OF EXPRESSION INTENSITY ON RECOGNIZING FEAR

Table 25

Proportion match for each Expression Intensity of fear

Intensity of Fear	*M*	*SD*	*t*	df	*p*
20	.14	.23	-4.65	59	< .001*
40	.32	.34			
20	.14	.23	-7.59	59	< .001*
60	.48	.36			
20	.14	.23	-7.88	59	< .001*
80	.52	.35			
20	.14	.23	-8.12	59	< .001*
100	.53	.33			
40	.32	.34	-3.74	59	< .001*
60	.48	.36			
40	.32	.34	-4.47	59	< .001*
80	.52	.35			
40	.32	.34	-4.25	59	< .001*
100	.53	.33			
60	.48	.36	-1.29	59	.200
80	.52	.35			
60	.48	.36	-1.37	59	.175
100	.53	.33			
80	.52	.35	-.23	59	.818
100	.53	.33			

Note. Bonferroni corrected paired t-tests. * $p < .005$.

APPENDIX P

EFFECT OF EXPRESSION INTENSITY ON RECOGNIZING HAPPINESS

Table 26

Proportion match for each Expression Intensity of happiness

Intensity of Happiness	*M*	*SD*	*t*	df	*p*
20	.64	.38	-5.14	59	< .001*
40	.83	.30			
20	.64	.38	-6.06	59	< .001*
60	.88	.26			
20	.64	.38	-5.51	59	< .001*
80	.88	.28			
20	.64	.38	-6.00	59	< .001*
100	.88	.27			
40	.83	.30	-2.56	59	.013
60	.88	.26			
40	.83	.30	-1.74	59	.086
80	.88	.28			
40	.83	.30	-1.90	59	.062
100	.88	.27			
60	.88	.26	.42	59	.673
80	.88	.28			
60	.88	.26	.26	59	.799
100	.88	.27			
80	.88	.28	-.20	59	.843
100	.88	.27			

Note. Bonferroni corrected paired t-tests. * $p < .005$.

APPENDIX Q

EFFECTS OF AGE AND EXPRESSION INTENSITY ON RECOGNIZING SADNESS

Table 27

Proportion match for sadness at all levels of Expression Intensity for younger and older adults

Intensity of Sad	Younger Adults					Older Adults				
	M	*SD*	*t*	df	*p*	*M*	*SD*	*t*	df	*p*
20	.26	.28	-6.46	30	< .001*	.13	.17	-5.04	28	< .001*
40	.73	.29				.41	.32			
20	.26	.28	-12.78	30	< .001*	.13	.17	-7.48	28	< .001*
60	.96	.15				.63	.36			
20	.26	.28	-11.34	30	< .001*	.13	.17	-7.82	28	< .001*
80	.91	.15				.64	.34			
20	.26	.28	-12.51	30	< .001*	.13	.17	-7.13	28	< .001*
100	.96	.11				.59	.35			
40	.73	.29	-4.55	30	< .001*	.41	.32	-3.36	28	.002*
60	.96	.15				.63	.36			
40	.73	.29	-3.93	30	< .001*	.41	.32	-4.11	28	< .001*
80	.91	.15				.64	.34			
40	.73	.29	-4.68	30	< .001*	.41	.32	-2.87	28	.01*
100	.96	.11				.59	.35			
60	.96	.15	1.53	30	.14	.63	.36	-.18	28	.86
80	.91	.15				.64	.34			
60	.96	.15	.00	30	1.00	.63	.36	.52	28	.61
100	.96	.11				.59	.35			
80	.91	.15	-1.79	30	.08	.64	.34	.84	28	.41
100	.96	.11				.59	.35			

Note: Bonferroni correct paired t-tests. * $p < .0025$.

APPENDIX R

EFFECT OF EXPRESSION INTENSITY ON RECOGNIZING SURPRISE

Table 28

Proportion match for each Expression Intensity of surprise

Intensity of Surprise	*M*	*SD*	*t*	df	*p*
20	.37	.31	-6.00	59	< .001*
40	.63	.27			
20	.37	.31	-3.83	59	< .001*
60	.59	.33			
20	.37	.31	-3.95	59	< .001*
80	.60	.29			
20	.37	.31	-3.23	59	.002*
100	.58	.30			
40	.63	.27	.90	59	.370
60	.59	.33			
40	.63	.27	.77	59	.442
80	.60	.29			
40	.63	.27	1.07	59	.287
100	.58	.30			
60	.59	.33	-.20	59	.840
80	.60	.29			
60	.59	.33	.29	59	.777
100	.58	.30			
80	.60	.29	.61	59	.546
100	.58	.30			

Note. Bonferroni corrected paired t-tests. * $p < .005$.

APPENDIX S

ATTRIBUTION MATRICES BY BLOCK OF TRIALS

Table 29

Emotion attributions made by younger adults over time

Emotion Displayed							
	Block 1						
	Emotion Selected						
	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.41	0.25	0.00	0.01	0.07	0.01	0.26
Disgust	0.29	0.46	0.01	0.01	0.05	0.02	0.16
Fear	0.01	0.02	0.44	0.01	0.07	0.39	0.06
Happy	0.00	0.00	0.01	0.93	0.01	0.01	0.04
Sad	0.03	0.03	0.01	0.00	0.78	0.01	0.13
Surprise	0.01	0.01	0.33	0.01	0.03	0.54	0.06
	Block 2						
	Emotion Selected						
	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.47	0.19	0.01	0.01	0.04	0.01	0.26
Disgust	0.21	0.54	0.04	0.01	0.02	0.03	0.16
Fear	0.00	0.03	0.57	0.00	0.03	0.29	0.08
Happy	0.00	0.00	0.00	0.93	0.01	0.02	0.05
Sad	0.02	0.06	0.02	0.00	0.74	0.01	0.15
Surprise	0.01	0.01	0.33	0.01	0.02	0.56	0.08
	Block 3						
	Emotion Selected						
	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.53	0.14	0.01	0.01	0.01	0.00	0.30
Disgust	0.23	0.53	0.00	0.01	0.04	0.03	0.16
Fear	0.00	0.02	0.55	0.00	0.06	0.30	0.06
Happy	0.00	0.00	0.00	0.96	0.01	0.00	0.03
Sad	0.01	0.02	0.03	0.00	0.78	0.01	0.15
Surprise	0.00	0.01	0.28	0.01	0.02	0.61	0.07
	Block 4						
	Emotion Selected						
	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.46	0.17	0.00	0.04	0.06	0.00	0.27
Disgust	0.28	0.43	0.01	0.03	0.03	0.03	0.19
Fear	0.00	0.01	0.50	0.00	0.07	0.33	0.09
Happy	0.00	0.00	0.00	0.95	0.00	0.01	0.04
Sad	0.03	0.03	0.02	0.00	0.76	0.01	0.15
Surprise	0.01	0.03	0.25	0.00	0.06	0.58	0.09

Table 30

Emotion attributions made by older adults over time

Emotion Displayed							
Block 1							
	Emotion Selected						
	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.07	0.13	0.03	0.01	0.32	0.02	0.42
Disgust	0.06	0.27	0.06	0.08	0.28	0.06	0.19
Fear	0.02	0.01	0.24	0.02	0.05	0.51	0.16
Happy	0.01	0.04	0.02	0.61	0.09	0.11	0.11
Sad	0.06	0.18	0.04	0.01	0.42	0.08	0.21
Surprise	0.01	0.02	0.13	0.10	0.03	0.61	0.10
Block 2							
	Emotion Selected						
	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.09	0.10	0.04	0.01	0.29	0.02	0.46
Disgust	0.09	0.28	0.04	0.05	0.26	0.08	0.21
Fear	0.06	0.04	0.26	0.04	0.03	0.43	0.14
Happy	0.01	0.02	0.02	0.69	0.06	0.08	0.12
Sad	0.09	0.14	0.05	0.00	0.46	0.06	0.20
Surprise	0.06	0.02	0.18	0.12	0.01	0.51	0.09
Block 3							
	Emotion Selected						
	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.07	0.11	0.02	0.01	0.26	0.03	0.50
Disgust	0.08	0.24	0.05	0.04	0.29	0.08	0.23
Fear	0.08	0.03	0.27	0.04	0.02	0.46	0.10
Happy	0.01	0.02	0.02	0.70	0.06	0.08	0.11
Sad	0.08	0.08	0.03	0.02	0.52	0.04	0.23
Surprise	0.04	0.02	0.25	0.08	0.02	0.49	0.11
Block 4							
	Emotion Selected						
	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger	0.09	0.14	0.02	0.01	0.24	0.02	0.48
Disgust	0.09	0.28	0.05	0.03	0.25	0.04	0.26
Fear	0.11	0.04	0.26	0.02	0.02	0.37	0.17
Happy	0.00	0.02	0.03	0.70	0.04	0.07	0.15
Sad	0.08	0.11	0.05	0.00	0.52	0.02	0.22
Surprise	0.05	0.03	0.19	0.11	0.01	0.49	0.11

APPENDIX T

SIMILARITY PROPORTIONS BY EXPRESSION INTENSITY

Table 31

Similarity proportions and emotion attributions for 20% intensity emotions

Emotion Displayed		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
	Anger							
	Similarity (total)	**1.00**	**0.97**	**0.93**	**0.91**	**0.93**	**0.92**	**0.97**
	Similarity (upper face)	*1.00*	*1.00*	*0.90*	*0.95*	*0.93*	*0.90*	*0.95*
	Similarity (lower face)	*1.00*	*0.94*	*0.95*	*0.86*	*0.94*	*0.93*	*0.98*
	YA Attribution	**0.09**	**0.08**	**0.01**	**0.07**	**0.02**	**0.01**	**0.73**
	OA Attribution	**0.05**	**0.04**	**0.01**	**0.02**	**0.08**	**0.04**	**0.77**
	Disgust							
	Similarity (total)	**0.97**	**1.00**	**0.94**	**0.91**	**0.93**	**0.94**	**0.95**
	Similarity (upper face)	*1.00*	*1.00*	*0.90*	*0.95*	*0.93*	*0.90*	*0.95*
	Similarity (lower face)	*0.94*	*1.00*	*0.99*	*0.86*	*0.94*	*0.98*	*0.94*
	YA Attribution	**0.06**	**0.16**	**0.03**	**0.04**	**0.05**	**0.03**	**0.62**
	OA Attribution	**0.03**	**0.02**	**0.02**	**0.05**	**0.16**	**0.08**	**0.65**
	Fear							
	Similarity (total)	**0.93**	**0.94**	**1.00**	**0.91**	**0.96**	**0.99**	**0.95**
	Similarity (upper face)	*0.90*	*0.90*	*1.00*	*0.95*	*0.97*	*1.00*	*0.95*
	Similarity (lower face)	*0.95*	*0.99*	*1.00*	*0.85*	*0.95*	*0.97*	*0.95*
	YA Attribution	**0.01**	**0.02**	**0.23**	**0.02**	**0.13**	**0.25**	**0.35**
	OA Attribution	**0.07**	**0.05**	**0.05**	**0.04**	**0.07**	**0.21**	**0.52**
	Happy							
	Similarity (total)	**0.91**	**0.91**	**0.91**	**1.00**	**0.90**	**0.92**	**0.95**
	Similarity (upper face)	*0.95*	*0.95*	*0.95*	*1.00*	*0.97*	*0.95*	*1.00*
	Similarity (lower face)	*0.86*	*0.86*	*0.85*	*1.00*	*0.80*	*0.88*	*0.88*
	YA Attribution	**0.00**	**0.00**	**0.01**	**0.80**	**0.02**	**0.01**	**0.16**
	OA Attribution	**0.01**	**0.03**	**0.02**	**0.47**	**0.10**	**0.04**	**0.33**
	Sad							
	Similarity (total)	**0.93**	**0.93**	**0.96**	**0.90**	**1.00**	**0.95**	**0.95**
	Similarity (upper face)	*0.93*	*0.93*	*0.97*	*0.97*	*1.00*	*0.97*	*0.98*
	Similarity (lower face)	*0.94*	*0.94*	*0.95*	*0.80*	*1.00*	*0.92*	*0.92*
	YA Attribution	**0.04**	**0.03**	**0.02**	**0.00**	**0.26**	**0.02**	**0.63**
	OA Attribution	**0.02**	**0.10**	**0.04**	**0.02**	**0.11**	**0.05**	**0.66**
	Surprise							
	Similarity (total)	**0.92**	**0.94**	**0.99**	**0.92**	**0.95**	**1.00**	**0.94**
	Similarity (upper face)	*0.90*	*0.90*	*1.00*	*0.95*	*0.97*	*1.00*	*0.95*
	Similarity (lower face)	*0.93*	*0.98*	*0.97*	*0.88*	*0.92*	*1.00*	*0.93*
	YA Attribution	**0.00**	**0.02**	**0.12**	**0.02**	**0.09**	**0.39**	**0.35**
	OA Attribution	**0.05**	**0.03**	**0.11**	**0.10**	**0.04**	**0.29**	**0.38**

Table 32

Similarity proportions and emotion attributions for 40% intensity emotions

Emotion Displayed		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
	Anger							
	Similarity (total)	**1.00**	**0.94**	**0.85**	**0.82**	**0.87**	**0.83**	**0.93**
	Similarity (upper face)	*1.00*	*0.99*	*0.81*	*0.90*	*0.86*	*0.81*	*0.91*
	Similarity (lower face)	*1.00*	*0.88*	*0.91*	*0.72*	*0.88*	*0.86*	*0.96*
	YA Attribution	**0.31**	**0.16**	**0.02**	**0.01**	**0.06**	**0.01**	**0.43**
	OA Attribution	**0.04**	**0.05**	**0.03**	**0.00**	**0.17**	**0.02**	**0.69**
	Disgust							
	Similarity (total)	**0.94**	**1.00**	**0.88**	**0.82**	**0.87**	**0.87**	**0.89**
	Similarity (upper face)	*0.99*	*1.00*	*0.80*	*0.90*	*0.85*	*0.80*	*0.90*
	Similarity (lower face)	*0.88*	*1.00*	*0.98*	*0.72*	*0.88*	*0.96*	*0.88*
	YA Attribution	**0.23**	**0.48**	**0.02**	**0.01**	**0.06**	**0.04**	**0.16**
	OA Attribution	**0.07**	**0.22**	**0.04**	**0.05**	**0.30**	**0.08**	**0.25**
	Fear							
	Similarity (total)	**0.85**	**0.88**	**1.00**	**0.81**	**0.92**	**0.97**	**0.90**
	Similarity (upper face)	*0.81*	*0.80*	*1.00*	*0.90*	*0.93*	*1.00*	*0.90*
	Similarity (lower face)	*0.91*	*0.98*	*1.00*	*0.70*	*0.91*	*0.94*	*0.91*
	YA Attribution	**0.00**	**0.03**	**0.40**	**0.00**	**0.08**	**0.47**	**0.02**
	OA Attribution	**0.07**	**0.04**	**0.23**	**0.03**	**0.02**	**0.49**	**0.11**
	Happy							
	Similarity (total)	**0.82**	**0.82**	**0.81**	**1.00**	**0.79**	**0.84**	**0.89**
	Similarity (upper face)	*0.90*	*0.90*	*0.90*	*1.00*	*0.95*	*0.90*	*1.00*
	Similarity (lower face)	*0.72*	*0.72*	*0.70*	*1.00*	*0.60*	*0.76*	*0.76*
	YA Attribution	**0.00**	**0.00**	**0.00**	**0.96**	**0.01**	**0.02**	**0.01**
	OA Attribution	**0.00**	**0.04**	**0.03**	**0.70**	**0.05**	**0.06**	**0.13**
	Sad							
	Similarity (total)	**0.87**	**0.87**	**0.92**	**0.79**	**1.00**	**0.89**	**0.90**
	Similarity (upper face)	*0.86*	*0.85*	*0.93*	*0.95*	*1.00*	*0.93*	*0.95*
	Similarity (lower face)	*0.88*	*0.88*	*0.91*	*0.60*	*1.00*	*0.84*	*0.84*
	YA Attribution	***0.06***	***0.07***	***0.04***	***0.00***	***0.73***	***0.01***	***0.09***
	OA Attribution	**0.07**	**0.16**	**0.05**	**0.00**	**0.39**	**0.08**	**0.24**
	Surprise							
	Similarity (total)	**0.83**	**0.87**	**0.97**	**0.84**	**0.89**	**1.00**	**0.88**
	Similarity (upper face)	*0.81*	*0.80*	*1.00*	*0.90*	*0.93*	*1.00*	*0.90*
	Similarity (lower face)	*0.86*	*0.96*	*0.94*	*0.76*	*0.84*	*1.00*	*0.86*
	YA Attribution	**0.01**	**0.02**	**0.24**	**0.01**	**0.05**	**0.66**	**0.02**
	OA Attribution	**0.05**	**0.03**	**0.16**	**0.08**	**0.02**	**0.56**	**0.11**

Table 33

Similarity proportions and emotion attributions for 60% intensity emotions

Emotion Displayed		Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
	Anger							
	Similarity (total)	**1.00**	**0.92**	**0.78**	**0.73**	**0.80**	**0.75**	**0.90**
	Similarity (upper face)	*1.00*	*0.99*	*0.71*	*0.86*	*0.79*	*0.71*	*0.86*
	Similarity (lower face)	*1.00*	*0.82*	*0.86*	*0.58*	*0.82*	*0.79*	*0.94*
	YA Attribution	**0.58**	**0.25**	**0.00**	**0.00**	**0.05**	**0.00**	**0.12**
	OA Attribution	**0.07**	**0.16**	**0.03**	**0.00**	**0.28**	**0.02**	**0.44**
	Disgust							
	Similarity (total)	**0.92**	**1.00**	**0.82**	**0.73**	**0.80**	**0.81**	**0.84**
	Similarity (upper face)	*0.99*	*1.00*	*0.70*	*0.85*	*0.78*	*0.70*	*0.85*
	Similarity (lower face)	*0.82*	*1.00*	*0.96*	*0.58*	*0.82*	*0.94*	*0.82*
	YA Attribution	**0.31**	**0.58**	**0.01**	**0.00**	**0.04**	**0.02**	**0.05**
	OA Attribution	**0.09**	**0.39**	**0.05**	**0.02**	**0.26**	**0.08**	**0.11**
	Fear							
	Similarity (total)	**0.78**	**0.82**	**1.00**	**0.72**	**0.88**	**0.96**	**0.85**
	Similarity (upper face)	*0.71*	*0.70*	*1.00*	*0.86*	*0.90*	*1.00*	*0.85*
	Similarity (lower face)	*0.86*	*0.96*	*1.00*	*0.54*	*0.86*	*0.90*	*0.86*
	YA Attribution	**0.00**	**0.02**	**0.61**	**0.00**	**0.04**	**0.33**	**0.00**
	OA Attribution	**0.06**	**0.01**	**0.30**	**0.03**	**0.02**	**0.52**	**0.05**
	Happy							
	Similarity (total)	**0.73**	**0.73**	**0.72**	**1.00**	**0.69**	**0.76**	**0.84**
	Similarity (upper face)	*0.86*	*0.85*	*0.86*	*1.00*	*0.92*	*0.86*	*0.99*
	Similarity (lower face)	*0.58*	*0.58*	*0.54*	*1.00*	*0.40*	*0.64*	*0.64*
	YA Attribution	**0.00**	**0.00**	**0.00**	**0.98**	**0.00**	**0.01**	**0.02**
	OA Attribution	**0.00**	**0.02**	**0.03**	**0.76**	**0.06**	**0.08**	**0.05**
	Sad							
	Similarity (total)	**0.80**	**0.80**	**0.88**	**0.69**	**1.00**	**0.84**	**0.85**
	Similarity (upper face)	*0.79*	*0.78*	*0.90*	*0.92*	*1.00*	*0.90*	*0.93*
	Similarity (lower face)	*0.82*	*0.82*	*0.86*	*0.40*	*1.00*	*0.76*	*0.76*
	YA Attribution	**0.00**	**0.01**	**0.01**	**0.00**	**0.96**	**0.01**	**0.02**
	OA Attribution	**0.07**	**0.15**	**0.02**	**0.02**	**0.62**	**0.04**	**0.08**
	Surprise							
	Similarity (total)	**0.75**	**0.81**	**0.96**	**0.76**	**0.84**	**1.00**	**0.82**
	Similarity (upper face)	*0.71*	*0.70*	*1.00*	*0.86*	*0.90*	*1.00*	*0.85*
	Similarity (lower face)	*0.79*	*0.94*	*0.90*	*0.64*	*0.76*	*1.00*	*0.79*
	YA Attribution	**0.00**	**0.01**	**0.37**	**0.00**	**0.02**	**0.60**	**0.00**
	OA Attribution	**0.06**	**0.02**	**0.17**	**0.12**	**0.01**	**0.61**	**0.02**

Table 34

Similarity proportions and emotion attributions for 80% intensity emotions

Emotion Displayed	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger							
Similarity (total)	**1.00**	**0.89**	**0.70**	**0.64**	**0.74**	**0.66**	**0.86**
Similarity (upper face)	*1.00*	*0.99*	*0.62*	*0.81*	*0.72*	*0.62*	*0.82*
Similarity (lower face)	*1.00*	*0.76*	*0.81*	*0.44*	*0.76*	*0.72*	*0.92*
YA Attribution	**0.69**	**0.18**	**0.00**	**0.00**	**0.06**	**0.00**	**0.06**
OA Attribution	**0.09**	**0.22**	**0.02**	**0.02**	**0.34**	**0.01**	**0.30**
Disgust							
Similarity (total)	**0.89**	**1.00**	**0.76**	**0.64**	**0.73**	**0.74**	**0.78**
Similarity (upper face)	*0.99*	*1.00*	*0.60*	*0.80*	*0.71*	*0.60*	*0.80*
Similarity (lower face)	*0.76*	*1.00*	*0.95*	*0.44*	*0.76*	*0.92*	*0.76*
YA Attribution	**0.35**	**0.57**	**0.01**	**0.01**	**0.02**	**0.02**	**0.01**
OA Attribution	**0.11**	**0.36**	**0.05**	**0.05**	**0.30**	**0.07**	**0.07**
Fear							
Similarity (total)	**0.70**	**0.76**	**1.00**	**0.62**	**0.84**	**0.94**	**0.80**
Similarity (upper face)	*0.62*	*0.60*	*1.00*	*0.81*	*0.86*	*1.00*	*0.80*
Similarity (lower face)	*0.81*	*0.95*	*1.00*	*0.39*	*0.81*	*0.87*	*0.81*
YA Attribution	**0.01**	**0.02**	**0.67**	**0.00**	**0.03**	**0.27**	**0.00**
OA Attribution	**0.08**	**0.04**	**0.33**	**0.02**	**0.02**	**0.51**	**0.01**
Happy							
Similarity (total)	**0.64**	**0.64**	**0.62**	**1.00**	**0.59**	**0.68**	**0.78**
Similarity (upper face)	*0.81*	*0.80*	*0.81*	*1.00*	*0.90*	*0.81*	*0.99*
Similarity (lower face)	*0.44*	*0.44*	*0.39*	*1.00*	*0.20*	*0.52*	*0.52*
YA Attribution	**0.00**	**0.00**	**0.00**	**0.99**	**0.00**	**0.00**	**0.01**
OA Attribution	**0.01**	**0.02**	**0.02**	**0.76**	**0.04**	**0.11**	**0.05**
Sad							
Similarity (total)	**0.74**	**0.73**	**0.84**	**0.59**	**1.00**	**0.78**	**0.80**
Similarity (upper face)	*0.72*	*0.71*	*0.86*	*0.90*	*1.00*	*0.86*	*0.90*
Similarity (lower face)	*0.76*	*0.76*	*0.81*	*0.20*	*1.00*	*0.68*	*0.68*
YA Attribution	**0.01**	**0.05**	**0.02**	**0.00**	**0.91**	**0.02**	**0.00**
OA Attribution	**0.12**	**0.14**	**0.03**	**0.00**	**0.64**	**0.05**	**0.02**
Surprise							
Similarity (total)	**0.66**	**0.74**	**0.94**	**0.68**	**0.78**	**1.00**	**0.76**
Similarity (upper face)	*0.62*	*0.60*	*1.00*	*0.81*	*0.86*	*1.00*	*0.80*
Similarity (lower face)	*0.72*	*0.92*	*0.87*	*0.52*	*0.68*	*1.00*	*0.72*
YA Attribution	**0.02**	**0.02**	**0.35**	**0.01**	**0.01**	**0.60**	**0.00**
OA Attribution	**0.05**	**0.00**	**0.27**	**0.11**	**0.01**	**0.57**	**0.01**

REFERENCES

Ambadar, Z., Schooler, J., & Cohn, J. (2005). Deciphering the Enigmatic Face. *Psychological Science*, *16*(5), 403-410. doi:10.1111/j.0956-7976.2005.01548.x

Bartneck, C. (2001). How convincing is Mr. Data's smile: Affective expressions of machines. *User Modeling and User-Adapted Interaction, 11*(4)*,* 279-295. doi:0.1023/A:1011811315582

Bartneck, C., Reichenbach, J., & Breeman, A. (2004). In your face, robot! The influence of a character's embodiment on how users perceive its emotional expressions. *Proceedings of the Design and Emotion*. Ankara, Turkey.

Beer, J. M. (2010). *Recognizing facial expressions of virtual agents, synthetic faces and human faces: The effects of age and character type on emotion recognition*. Unpublished manuscript, School of Psychology, Georgia Institute of Technology, Atlanta, GA.

Beer, J. M., Fisk, A. D., & Rogers, W. A. (2009). Emotion recognition of virtual agent facial expressions: The effects of age and emotion intensity. *Proceedings of the Human Factors and Ergonomics Society 53rd Annual Meeting* (pp. 131-135). Santa Monica, CA: Human Factors and Ergonomics Society.

Beer, J. M., Fisk, A. D., & Rogers, W. A. (2010). Recognizing emotion in virtual agent, synthetic human, and human facial expressions. *Proceedings of the Human Factors and Ergonomics Society 54th Annual Meeting* (pp. 2388-2392). Santa Monica, CA: Human Factors and Ergonomics Society.

Benton, A. L., Eslinger, P. J., & Damasio, A. R. (1981). Normative observations on neuropsychological test performances in old age. *Journal of Clinical Neuropsychology, 3*(1), 33-42.

Bould, E., & Morris, N. (2008). Role of motion signal in recognizing subtle facial expressions of emotion. *British Journal of Psychology, 99*, 167-189. doi:10.1348/000712607X206702

Bould, E., Morris, N., & Wink, B. (2008). Recognising subtle emotional expressions: The role of facial movements. *Cognition & Emotion, 22*(8), 1569-1587. doi:10.1080/02699930801921156

Calder, A. J., Keane, J., Manly, T., Sprengelmeyer, R., Scott, S., Nimmo-Smith, I., & Young, A. W. (2003). Facial expression recognition across the adult life span. *Neuropsychologia, 41*(2), 195-202.

Calder, A. J., Keane, J., Young, A. W., & Dean, M. (2000). Configural information in facial expression perception. *Journal of Experimental Psychology: Human Perception and Performance, 26,* 527–551.

Carroll, J. M., & Russell, J. A. (1997). Facial expressions in Hollywood's portrayal of emotion. *Journal of Personality and Social Psychology*, *72*(1), 164-176.

Carstensen, L. L., & Mikels, J. A. (2005). At the intersection of emotion and cognition: Aging and the positivity effect. *Current Directions in Psychological Science, 14*(3), 117-121.

Czaja, S. J., Charness, N., Fisk, A. D., Hertzog, C., Nair, S. N., Rogers, W. A., & Sharit, J. (2006). Factors predicting the use of technology: Findings from the Center for

Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and Aging, 21*(2), 333-352.

Ekman, P. (2003). *Emotions revealed. Understanding faces and feelings*. London, United Kingdom: Phoenix.

Ekman, P., & Friesen, W. V. (1976). Ekman, P. & Friesen, W. V. (1975). *Unmasking the face: A guide to recognizing emotions from facial clues*. Englewood Cliffs, New Jersey: Prentice-Hall.

Ekman, P., & Friesen, W. V. (1976). *Pictures of facial affect*. Palo Alto, CA: Consulting Psychologist Press.

Ekman, P., & Friesen, W. V. (2003). *Unmasking the face: A guide to recognizing emotions from facial expressions*. Cambridge, MA: Malor Books.

Ekman, P., Friesen, W. V., & Ellsworth, P. (1982). Does the face provide accurate information? In P. Ekman (Ed.), *Emotion in the human face* (2nd ed.) (pp. 56-97). Cambridge, United Kingdom: Cambridge University Press.

Fisher, D. L., & Tanner, N. S. (1992). Optimal symbol set selection: A semiautomated procedure. *Human Factors, 34*(1), 79-95.

Franklin, S., & Graesser, A. (1996). Is it an agent, or just a program? A taxonomy for autonomous agents. In J. P. Muller, M. J. Wooldridge, & N. R. Jennings (Eds.), *Intelligent Agents III – Proceedings of the Third International Workshop on Agent Theories, Architectures, and Languages* (pp. 21-36). Heidelberg, Germany: Springer-Verlag.

Goetz, J., Kiesler, S., & Powers, A. (2003). Matching robot appearance and behavior to tasks to improve human-robot cooperation. *Proceedings of the 2003 IEEE International Workshop on Robot and Human Interaction Communication,* 55-60.

Isaacowitz, D. M., Lockenhoff, C. E., Lane, R. D., Wright, R., Sechrest, L., Riedel, R., & Costa, P. T. (2007). Age differences in recognition of emotion in lexical stimuli and facial expressions. *Psychology and Aging, 22*(1), 147-159.

Kanda, T., & Ishiguro, H. (2006). An approach for a social robot to understand human relationships: Friendship estimation through interaction with robots. *Interaction Studies, 7,* 369-403.

Levin, H. S., Hamsher, K. S., & Benton, A. L. (1975). A short form of the test of facial recognition for clinical use. *Journal of Psychology, 91*, 223–228.

Mather, M., & Carstensen, L. L. (2003). Aging and attentional biases for emotional faces. *Psychological Science, 14*(5), 409-415.

McDowd, J. M., & Craik, F. I. M. (1988). Effects of aging and task difficulty on divided attention performance. *Journal of Experimental Psychology: Human Perception and Performance, 14*, 267–280.

McKelvie, S. J. (1995). Emotional expression in upside-down faces: Evidence for configuration and componential processing. *British Journal of Social Psychology, 34*, 325-334.

Minsky, M. (1988). *The Society of the Mind*. New York: Simon & Schuster.

Nass, C., Moon, Y., Fogg, B. J., Reeves, B., & Dryer, D. C. (1995). Can computer personalities be human personalities? *International Journal of Human-Computer Studies, 43,* 223-229.

Phillips, L. H., & Henry, J. D. (2005). An evaluation of the frontal lobe theory of cognitive aging. In: J. Duncan, L. H. Phillips, & P. McLeod (Eds.), *Measuring the Mind: Speed, Control and Age* (pp. 191–216). Oxford, United Kingdom: Oxford University Press.

Posner, M. I. (1978). *Chronometric Explorations of Mind*. Hillsdale, NJ: Lawrence Erlbaum.

Psychological Software Tools. (2008). E-prime version 2.0, [http:www.pstnet.com]. (Computer software and manuals).

Raz, N., Gunning, F. M., Head, D., Dupuis, J. H., McQuain, J., Briggs, S. D., … Acker, J. D. (1997). Selective aging of the human cerebral cortex observed in vivo: differential vulnerability of the prefrontal gray matter. *Cerebral Cortex, 7*, 268–282.

Ruffman, T., Henry, J. D., Livingstone, V., & Phillips, L. H. (2008). A meta-analytic review of emotion recognition and aging: Implications for neuropsychological models of aging. *Neuroscience & Biobehavioral Reviews, 32*(4), 863-881.

Russell, S. J., & Norvig, P. (1995). *Artificial intelligence: A modern approach*. Englewood Cliffs, NJ: Prentice Hall.

Salthouse, T. A. (1992). Mechanisms of age-cognition relations in adulthood. J. M. MacEachran Memorial Lecture Series. Hillsdale, NJ: Erlbaum.

Sheridan, T. B. (1992). *Telerobotics, automation, and human supervisory control*. Cambridge, MA: MIT Press.

Shipley, W. C. (1986). Shipley institute of living scale. Los Angeles: Western Psychological Services.

Smarr, C.-A., Fausset, C. B., & Rogers, W. A. (2011). *Understanding the potential for robot assistance for older adults in the home environment* (HFA-TR-1102). Atlanta, GA: Georgia Institute of Technology, School of Psychology, Human Factors and Aging Laboratory.

Snellen, H. (1868). Test-types for the determination of the acuteness of vision (4th ed.). London: Williams & Norgate.

Sullivan, S., & Ruffman, T. (2004). Emotion recognition deficits in the elderly. *International Journal of Neuroscience, 114*(3), 403-432.

Sullivan, S., Ruffman, T., & Hutton, S. B. (2007). Age differences in emotion recognition skills and visual scanning of emotion faces. *Journals of Gerontology: Series B: Psychological Sciences and Social Sciences, 62B*(1), 53-60.

Verhaeghen, P., & Cerella, J. (2002). Aging, executive control, and attention: a review of meta-analyses. *Neuroscience and Biobehavioral Reviews, 26*, 849–857.

Wechsler, D. (1997). Wechsler adult intelligence scale III. (3rd ed.). San Antonio, TX: The Psychological Corporation.

Wehrle, Kaiser, Schmidt, & Scherer. (2000). Studying the dynamics of emotional expression using synthesized facial muscle movements. *Journal of Personality and Social Psychology, 78*(1), 105-119. doi:10.1037/0022-3514.78.1.105.

Wong, B., Cronin-Golomb, A., & Neargarder, S. (2005, November). Patterns of Visual Scanning as Predictors of Emotion Identification in Normal Aging. *Neuropsychology*, *19*(6), 739-749.

Wooldridge, M., & Jennings, N. R. (1995). Intelligent agents: Theory and practice. *Knowledge Engineering Review, 10,* 115-152.